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Human factors in destroyer operations.

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THESIS

HUMAN FACTORS IN DESTROYER OPERATIONS

by

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Human Factors in Destroyer Operations

by

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ABSTRACT

A study was made of human factors affecting operations of U.S. Navy destroyers. Shipboard duties were analyzed to determine factors relevant to job performance. These factors were then considered in the light of related laboratory experiments, field and exercise results, and modern theory, to determine where improved performance could be achieved within existing personnel and material resource constraints.

Topics include vigilance and motivation; search techniques; sensor optimization; man's total environment (factors such as fatigue, stress, lighting, temperature, noise, medication, and smoking); group and individual psychological needs; human engineering requirements; and typical performance effectiveness criteria.

The author has completed department head tours in nuclear attack submarines and guided missile frigates. He is a surface warfare specialist, qualified in submarines, and qualified for command of destroyers (189 pages plus 373 item bibliography).

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I. PREFACE

Human factors is not an exact science, but an art in which the operator cannot be expected to attain absolute perfection. However, consideration of the factors discussed in this paper will make "absolute perfection" a little less unattainable. This paper does not examine equipment design per se, although in many cases increased efficiency could be realized through better human engineering. Baker, C. H. (1962) discussed one case where such changes appear necessary:

> "The machine (airplane) itself is always an engineering marvel, the radar electronics are usually excellent, but, almost invariably, the actual operating end of the radar where one receives the information for which all the money was spent, is an unfortunate combination of design and operating errors. As a consequence, the effectiveness of the whole system is largely vitiated."

This paper examines the performance of man in the context of a larger system, the U.S. Navy Destroyer. Where man's performance can be improved the system will often perform better, often dramatically so (Teel, 1971). If such gains can be achieved with only slight or inexpensive human factor adjustments, then such adjustments can become an important and useful tactic in our efforts to improve overall operations.

Some readers may be uncomfortable with the unusual approach taken in presenting various principles. Stress, for example, will be found discussed in the context of the Officer of the Deck. Search Technique, under the Lookout.

It would have been possible to have discussed the principles as chapters themselves, and then simply suggested which persons might be most affected. The Author believes that he has selected the more readable presentation; and since the actual "operating end" of this paper will be the reader, it seems apropos to consider him first in the design of the paper.

The intended reader is not just upper level management. It is felt that after reading this paper, anyone can gain a little better understanding of how he performs in a variety of situations. For certain deficiencies, understanding becomes the key to improvement. So that this paper can be made widely available, it has been kept unclassified. Nothing has been lost by this; human factors principles are general principles, and where applicability to a specific piece of equipment or classified operating procedure may exist, applicability exists in the unclassified sense also.

Undoubtedly, the number of bibliographical references will be distracting to some. Unfortunately this is the nature of the subject and the Author can only be apologetic of the fact. He also apologizes to those nameless authors who might find their original conceptions unintentionally adopted here without proper credit. An assumption made in this paper was that references would not be available to the reader, and where some additional information might be necessary for understanding a certain idea, that information was provided in the text.

II. INTRODUCTION

Human factors in the original sense are the component capabilities and limitations of man which in total determine how he will function as a seeing, hearing, manipulating, talking, and understanding mechanism. Human factors as a discipline has emerged as a recognizable specialty only during the first several decades of this century. As a discipline, human factors is a direct descendant of industrial engineering and psychology, the later science evolving about the same time from its original foundations of physiology and philosophy. Meister and Rabideau (1965) provide a historical review of early literature in this field. Lately, the term human factors has developed many different connotations. The most comprehensive listing and discussion of present usages is contained in Meister (1971).

In this paper we will be concerned with human factors principles as they apply to the existing shipboard environment. We will examine exercises and experiments for instances where human operators have had an observed effect on total system performance. From analysis of these effects, and application of existing human factors theory, we intend to develop practical recommendations for specific actions a Commanding Officer may take to improve the performance of man-machine systems under his control.

Although this paper is the first attempt to apply human factors principles to overall destroyer operations, military

interest in the subject goes back to studies of problems connected with flying in World War I. Later, the greatly increased technology of World War II created an urgent need for expanded human factors research and development. The U.S. Navy Operations Evaluation Group (OEG) was formed at this time to develop ways to best use existing equipment to combat the Soviet U-Boat (Steinhardt, 1946). Although human factors had not yet surfaced as a recognizable specialty, OEG was in fact pioneering in this field. Much of their work was classified, but in the spring of 1947 the first coherent public discussion of the subject was conducted at the Naval Postgraduate School, Annapolis, Maryland. The papers presented at that time were significant milestones in that for the first time a large group of engineering officers -- men who in the future would be responsible for putting human engineering to work in the navy, were finding out what human engineering was all about. These published papers are found in Chapanis, and others (1947).

Other publications began to appear forming an expanding body of unclassified human factors literature. Included were Loucks (1944), Anderson, and others (1944), Office of Scientific Research and Development (1945), Garner (1946,a), Chapanis (1946), and Garner, Hanes, and Reed (1947). McGrath, Harabedian, and Buckner (1959), and Brictson (1971) provide reviews of later literature in this field.

A. HUMAN FACTORS REQUIREMENTS

From this beginning the military has developed an ever increasing awareness of the subject, and now includes human factors specifications in all new systems and equipment designs:

1. MIL-STD-1472A, 15 May 1970, Human Engineering Design Criteria for Military Systems, Equipment and Facilities

2. MIL-H-24148, 3 June 1968, Human Engineering Requirements for Bureau of Ships Systems and Equipment

3. MIL-H-46855A, 2 May 1972, Human Engineering Requirements for Military Systems, Equipment and Facilities

4. MIL-H-81444, 1 September 1966, Human Factors Engineering Systems Analysis data.

These equipment design standards represent individual tactics in our modern approach to obtaining optimum performance from systems. All systems, at some point, require human operation. If a system is not operating optimally, or if operation at a particular level requires too great an expenditure of human resources, often knowledge and application of certain human factors principles can provide us with a policy to achieve greater efficiency or a higher level of performance.

An overall policy or strategy is clearly needed. Simply increasing lighting, moving status boards or writing design standards, as knee-jerk responses to certain specific complaints or suggestions does no more towards improving the overall operation of a destroyer today than it did for a corporation in 1946:

> ...The president of a large corporation recently put this question to me: "For the past fifteen years we have been making surveys of employee attitudes. Our assumption was that when we got this material we would have a good guide to company policy in employer-employee relations. We have been disappointed. We got lots of suggestions for tactics but few which helped us to formulate strategy. As a result we have installed washrooms, changed lighting, adopted various benefit schemes, revised our incentive system, and made other adjustments. But the basic nature of the human being, the basic principles that govern his reactions to the environment we create for him, the knowledge that would enable us to predict how our workers will react to a given change, such things are still cloudy. We need to grasp those things in order to devise strategy and policy. A fifteen-foot shelf of reports and no answers to these fundamental questions. Why?" ...
>
> E. Wight Bakke
> Director,
> Yale University
> 1946

The strategy we employ today may be given any of several labels:

1. Leadership
2. Organizational Performance and Human Effectiveness Practices
3. Human Resource Management
4. Management

However the objective remains the same: to do more, and to do it better, with less. Although there may be a difference in philosophy between these four schools, the recommendations of this paper are interdisciplinary and should apply in general to the Navy destroyer as a man-machine system.

It is important to place the scope of this paper in perspective, and to consider its relevance in today's military environment. First, the modern destroyer is an extremely

complex weapons system, with a multiplicity of equipments and subsystems. She is manned by a crew of individuals who belong to different groups at different times and who have both individual and group motivations and aspirations. The destroyer's mission varies, as does the environment and condition under which she is required to operate. In this paper, only certain individuals or watchstations will be discussed. Further applications can be made by individual Commanding Officers. What should always be considered is the effect of a particular innovation on the <u>system</u>, in this case the destroyer. For example, the methods we might adopt if we were interested only in achieving the greatest number of initial detections by lookouts would be different from what we'd do if we were also interested in the speed and accuracy of reporting, processing, and displaying that information. From the standpoint of optimizing overall destroyer performance, we must be concerned with all these later aspects of the lookout's function, plus the ability of the propulsion plant and steering systems to carry out any actions ordered as a result of this information.

At the same time we are optimizing on the level of our single destroyer, others are carrying out similar processes at the Squadron level, Fleet level, and Department of Defense level, to name but a few. The personnel and equipment resources which we have to work with are assumed to be those which exist on our ship today. We have only a limited ability to change equipments once provided, or to

increase manning levels once established. This paper does not discuss specific design improvements which could be made to existing equipments, nor does it make naive recommendations requiring overall increases in manpower above existing levels. Since Commanding Officers do have local authority to approve or initiate certain changes which may have human factor impact, a brief check-list is provided which may serve as a general guide in these situations.

It seems likely that future personnel resources will remain scarce and cost more. The people who we do have must function as effectively and efficiently as possible, and as a consequence human factors knowledge related to this objective becomes increasingly important. The following messages to all navy men from the Chief of Naval Operations provides additional incentive:

"...THE NAVY'S GREATEST RESOURCE LIES IN OUR HUMAN ASSETS...MY OBJECTIVE IS TO IMPROVE THE MANAGEMENT OF OUR HUMAN RESOURCES BY ENHANCING OUR UNDERSTANDING OF...PEOPLE

November 1970 (Z-55)

"...IN THE COMING YEARS OUR CHALLENGE PROMISES TO BE EVEN GREATER THAN IN THE PAST. AS THE ALL-VOLUNTEER NAVY DRAWS CLOSER AND AUSTERITY CONTINUES TO REDUCE OUR FUNDING, IT WILL BE INCREASINGLY NECESSARY THAT EACH INDIVIDUAL SHOULDER A LARGER PORTION OF THE JOB...

July 1971 (Z-93)

"...TO PROVIDE SUPPORT TO ALL NAVAL UNITS IN MEETING THE REQUIREMENTS OF THE 1970'S...DEVELOP AND IMPLEMENT BOTH EDUCATIONAL AND ORGANIZATIONAL IMPROVEMENT PROGRAMS WHICH PROVIDE THE MEANS TO ACHIEVE INCREASED COMMAND EXCELLENCE THROUGH INTEGRATION OF MEN AND MISSION IN A WAY THAT THE SKILLS AND CREATIVITY POSSESSED BY NAVY PERSONNEL WILL BE FULLY UTILIZED...THE SUPPORT OF ALL NAVY MEN AND WOMEN IS NEEDED IN THE IMPLEMENTATION OF THESE NEW INITIATIVES IN ORDER THAT WE MAY DEVELOP AN ENVIRONMENT TO IMPROVE BOTH THE SATISFACTION AND THE EFFECTIVENESS OF EACH INDIVIDUAL IN THE NAVY."

April 1972 (Z-110)

B. HUMAN GOALS AND HUMAN FACTORS

The U.S. Navy's recently implemented Human Goals Plan (OPNAVINST 5300.6, 1973) is intended "to ensure the development of the full potential of its human resources and application of that potential toward maximum effectiveness in the performance of the Navy's primary mission." The programs which comprise the Navy's Human Goals Plan are organized into five major categories:

1. Human Resource Management consisting of:
   - Organizational Development and Management
   - Intercultural Relations
   - Race Relations, and
   - Drug and Alcohol Education
2. Equal Opportunity
3. Drug and Alcohol Abuse Control
4. Career Motivation
5. TRANSITION/Second Career Planning and Assistance

An objective of this paper is to draw attention to the fact that human factors must also be considered in achieving this desired goal of maximum effectiveness. The human factors to be discussed in this paper are the variables involved in:

1. The characteristics (capabilities and limitations) of man
2. The characteristics (design features) of individual equipment and machine systems
3. The relationships between them.

C. RESEARCH EFFORT

Over one thousand human factor related documents have been reviewed in preparing this paper, and many of these

were summaries of additional experiments or studies. Most of this literature can be categorized as emphasizing one or more of the following functional areas. Significant documents in each category are referenced.

1. Human Factors Engineering. Emphasis on equipment design. Bennet, Degan, and Spiegel (1963), Chapanis (1965), Machol (1965), Meister and Rabideau (1965), McCormick (1970), Meister (1971), and Van Cott and Kinkade (1972) are representative.

2. Human Performance. Emphasis on psychological and physiological factors. Broadbent (1958), Jayle, and others (1959), Swets (1964), Green and Swets (1966), Fitts and Posner (1967), and Kryter (1970) might be included in this category.

3. Systems Analysis. Current literature emphasizes the man-machine relationship and blends the equipment design factors with human performance characteristics. As such, this category overlaps the preceding two. The important distinction is that here we have an attempt to evaluate the product of man-machine combinations in order to optimize the product for a given expenditure on the machine and its associated personnel. Goldhamer (1950) can be singled out for its historical precedence. Singleton, Easterby, and Whitfield (1967) provide a convenient collection of articles emphasizing this systems approach.

4. Analysis of Operations. Analysis of observations of exercise or field data. Byrd (1930), Wolfe and Mulholland (1960), Poulton (1965), Radloff and Helmreich (1968), Layton, Sandeen, and Baker (1971), and Destroyer Development Group (1973) are examples.

5. Vigilance. McGrath, Harabedian, and Buckner (1959), McGrath (1961), Franklin, Schumacher, and Tiedemann (1964), and Halcomb and Blackwell (1969) provide bibliographies, summaries and abstracts of vigilance literature. Basic texts include Buckner and McGrath (1963), Davies and Tune (1969), and Mackworth (1970).

6. Reliability. Several publications on reliability include significant discussions of the human factor as it affects system reliability. Aerospace Reliability and Maintainability Conference (1964), Miller, G.E., and others (1964) and Ireson (1966) are among the most complete.

7. Human Performance Models and Simulations. Variables considered in these models give insight into real world variables which we may use to improve human performance. Moore and Work (1967), Levy, G.W. (1969), Smith, R.L., Westland, and Blanchard (1969,a,b), Siegel and Wolf (1969), and Meister and Ramo (1971) are good examples.

8. Management and Leadership. Very often successful management or leadership practices derive their success from fundamental human factors principles. Taylor (1919), Wolfe and others (1959), Roethlisberger and Dickson (1967), Eddy, and others (1969), Donnelly, Gibson, and Ivancevich (1971), Cleland and King (1972), Hampton (1972), and Lawless (1972) are management oriented references.

In every case, regardless of the author's emphasis, what was looked for were clues or practices which would lead to a recommendation as to how a destroyer Commanding Officer might create a more favorable human factors environment or achieve better performance through improved human factors practices. The bibliography has excluded many references which are undoubtedly well known and widely used by various human factor specialists. For the most part, included material provides insight about human factor variables which might be changed to improve system performance. Other excluded materials were either outdated or had been incorporated in later publications. In some cases, older literature is referenced for its historical value. This paper is based on experimental results and technical reports which were available at the Naval Postgraduate School, and on modern theories of motivational behavior and vigilance. For those with access to the NPS Library, technical reports are referenced in standard bibliographical form (Thesis Manual, 1973) followed by the NPS Library Accession Number in parenthesis.

D. GENERAL PRUDENTIAL RULE

Finally, in a paper such as this, no claim of correctness should ever be made. Many of the proposals are based on laboratory studies. Chapanis (1967), a pioneer in human factors research, summarized the problem:

"By their very nature laboratory experiments are at best only rough and approximate models of any real-life situation. First, of all the possible independent variables that influence behaviour in any practical situation, a laboratory experiment selects only a few for test. As a result, hidden or unsuspected interactions in real-life may easily nullify, or even reverse, conclusions arrived at in the laboratory. Second, variables always change when they are brought into the laboratory. Third, the effect of controlling extraneous or irrelevant variables in the laboratory is to increase the precision of an experiment but at the risk of discovering effects so small that they are of no practical importance. Fourth, the dependent variables (or criteria) used in the laboratory experiments are variables of convenience. Rarely are they selected for their relevance to some practical situation. Last, the methods used to present variables in the laboratory are sometimes artificial and unrealistic. The safest and most honest conclusion to draw from all these considerations is that one should generalize with extreme caution from the results of laboratory experiments to the solution of practical problems."

All too often human factors research obtains results similar to a now famous two year study undertaken by the Hawthorne Works of the Western Electric Company (Chapanis, and others, 1947). The experiment was a very simple one involving five women who were assembling telephone relays. As reported:

"He (The Experimenter) gave them two 5-minute rest periods—production went up. He gave them two 10-minute rest periods—production went up some more. He took away the rest periods—production still went up some more. He gave them rest periods again—production went up. He gave them free lunches—production went up. He took away the free lunches—production still went up."

As an analyst, this experimenter could have simply selected the measure which increased production the most, and recommended this to the Electric Company management. The artifact which he would have missed would have been that of morale — the girls knew they were being given special consideration and they felt they were an important part of the experiment. Anything the experimenter did resulted in more production. This is a frequent result when we have poor experimental controls; and it is an unfortunate fact that applied research, and field experiments, simply do not have the controls which are possible in good laboratory research.

Many basic human factors principles are involved in each activity of man. In complex activities such as the vigilance and control functions of destroyer watchstanders we find that different factors assume greater significance in some situations than they do in others. The combinations and dominances of various factors is dynamic and independence between factors seldom exists. However some generalizations might be made by observing that at each watchstation man must perform some unique function. We can determine what factors seem to have the greatest relevance to that function, and then discuss principles and develop recommendations that might be applied to improve system performance. Although particular watchstations are cited, the principles and recommendations are not unique and might be applied in general to similar situations.

This paper attempts to be skeptical about much of what human factors claims to offer in an applied sense, and the reader too should be skeptical about adapting any general recommendations to his particular circumstances. It is hoped however that in many cases the information will be useful, and the recommendations "worth a try."

III. RADAR OPERATOR

A. VIGILANCE

1. Definition

Vigilance is such a pervasive factor of the human endeavor that it is difficult to name a single task which does not require some measure of vigilance. Vigilance principles applied to the Radar Operator can be applied almost without modification to every other watchstation discussed in this paper. Understanding the principles of vigilance is a prerequisite to successful application of human factors methodology to the field of Destroyer operations. Almost any condition measured, sensed, or manipulated by man seems to have some effect on his vigilance performance. Smith's (1966) basic vigilance model has nine "major" variables and a number of "minor" variables, and requires four assumptions and three supporting corollaries.

The ancient rule of the prudent mariner was echoed in a Pacific Fleet Letter by then Fleet Admiral Chester W. Nimitz, U.S. Navy when he wrote (Noel, 1960): "Eternal vigilance is the price of safety," and at least one ship, the USS JOUETT (DLG-29) has adopted as a motto the words: "Eternal Vigilance." But how eternal can vigilance really be, and what is the true nature of this almost intangible commodity?

In this conventional usage, "vigilance" is characterized by an alertness to danger, or watchfulness. But

"vigilance" has a slightly different meaning in human factors literature. Historically, according to Marshall (1970):

"A by-product of ...(man's)...evolution towards automation has been the requirement for man to monitor the operation and/or the output of a system. This new requirement for man has resulted in the observance of a definite decrement in the ability to effectively perform monitoring tasks of a routine nature. One of the first extensive studies of this monitoring decrement was performed by Mackworth (1950). In his study, Mackworth introduced the term "vigilance" to refer to an observer's readiness to detect infrequent, aperiodic, small changes in the environment."

Today, it is quite common to find "vigilance" defined as a detection problem, "...characterized by extended periods of continuous observation. Signals can occur at any time during the long period, without warning ..." (Green and Swets, 1966).

Mackworth should be credited not only with introducing a new meaning for vigilance, but also for forming the mold in which a never ending stream of vigilance experiments has poured from. Within barely seven years of Mackworth's study, the Medical Research Council (1957) was able to identify the following variables as effecting a common vigilance (inspection) task:

"(1) Inherent task conditions. Under this heading (a) the frequency of faults; (b) the type of fault; (c) the difficulty of the discrimination required; (d) the number of objects displayed simultaneously; (e) the number of dimensions on which the objects vary; (f) the temporal structure of the sequence of faults; (g) the distribution of faults of different kinds and degrees; (h) the 'meaningfulness' of the task, that is, the nature of the objects to be examined; (i) the number of classes into which the objects must be sorted; (j) the number and nature of 'additional' operations required (for example, 'booking').

"(2) External conditions. These include variables like (a) the speed at which the task must be performed; (b) the total length of the task; (c) the frequency of the rest-pauses;

(d) the effects of various kinds of interpolated activity during breaks on subsequent performance; (e) the degree of isolation of the subject; (f) illumination, contrast, noise and atmospheric conditions; (g) time of day or night, lack of sleep; (h) knowledge of results, that is, awareness of performance efficiency; (i) amount and nature of reward, that is, incentive systems; (j) presence or absence of objective reference standards, and their intermittent variation.

"(3) Individual variability."

By late 1968, more than 300 vigilance studies had been completed in the Mackworth tradition (Smith and Lucaccini, 1969). "New" factors continue to be added almost daily, and lists could be drawn up which include different and additional factors for each individual vigilance task. The objective of this paper is not to cite all the possible variables effecting shipboard vigilance, but rather to select and examine in turn those factors about which we are traditionally the most concerned, or over which we have the means to change to advantage. The first of these factors is "Time on Watch."

2. Vigilance Decrement with Time

The flood of previously mentioned vigilance studies continues unabated today, and from this deluge there seems to have developed a certain "Mariner's Law" which states: "Maximum vigilance can be maintained for a period of about 30 minutes, after this performance deteriorates sharply." Lookouts are rotated, and sonar operators are periodically spelled, in accordance with this law. The Law, however, was repealed by Elliott (1960):

"Until recently, at least, researchers have been greatly preoccupied with what might be terned the Mackworth 'A' effect. This effect appeared in the Clock Test (Mackworth 1950) in which the watchkeeper's performance deteriorated after about 30 min and then was maintained at about the same impoverished level for a further 90 min. This form of behaviour has never been found in any closely simulated radar or asdic (sonar) search. Occasionally, when operators have been subjected to an arduous series of watches a 'fatigue' effect has been observed, but it has been a continuous degradation of performance throughout the watch. More commonly there are no 'fatigue' effects during continuous two-hour watches. What we might call the Mackworth 'B' effect also leads to some disconcerting observations. This effect was seen in the first 30 min of the Clock Test, where operators missed about 15 per cent of the signals which a completely efficient operator would have detected (in the subsequent 90 min the rate of missed signals increased to nearly 30 per cent). In other words, the vigilance situation was such that operators were immediately inefficient at the beginning of a watch. In military tasks we do find this 'B' effect, and it is the effect which plainly limits the efficiency of a search system. Despite this, and the fact that the 'B' effect is a little larger than the 'A' effect (at least in Mackworth's own experiments) the 'B' effect has received little attention: it is often quite ignored while theories explaining the 'A' effect are developed in profusion, and experiments to test such theories are multiplied."

Teichner (1972) waded through the pool of available vigilance literature published between 1950 and 1971 and extracted methodological information and actual data. Based on analysis of this data three major factors appear to influence the probability of detecting a visual signal as a function of time of watch:

"(1) the initial percentage or probability of detection, i.e. the normal or pre-test level,

"(2) the duration of the watch, and

"(3) whether the signal-eye relationship is static or dynamic, i.e. whether it produces or demands continuing changes in state or position of the eye (dynamic) or does not (static).

"... it is worth noting ... that we could locate only two acceptable data sets using radar simulation ... In neither case was there a decrement in performance with time."

Figure 1 is a family of curves obtained by superimposing plots of performance vs. time for experiments with different ranges of initial detection probabilities. There are some important similarities among the curves. First, the

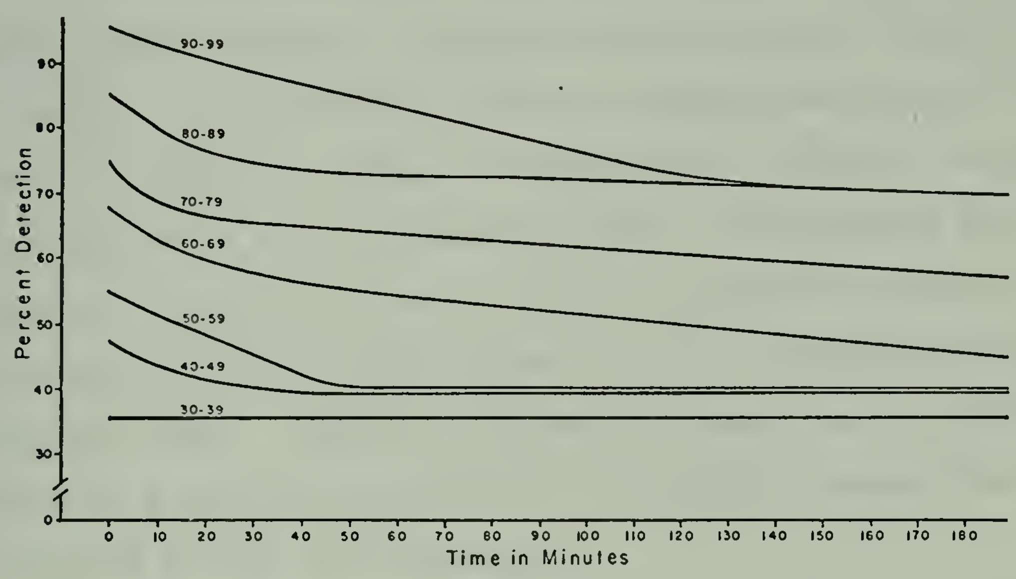

FIGURE 1 Per Cent Detections vs. Time on Watch for various initial detection probabilities (Teichner, 1972)

maximum decrement is fairly small in all cases. Although some of the curves appear to have the same asymptotes, the general impression is of a family of negatively accelerated, decreasing functions. Secondly, no decrement is suggested for the 30 to 39 per cent interval. Where the task provides only a small initial probability of detection, there appears to be no "time on watch" effect. It is this latter type of

low probability environment that shipboard watchstanders frequently encounter. This fact suggests that we should not be preoccupied with providing relief for such watchstanders every 30 minutes, when there are more significant human factors which should be occupying our attention.

This is not to say that during periods of sonar contact prosecution, fire control engagement, or multiple target radar tracking, 30 minute breaks offer no advantage. A possible interpretation (there are many; Davies and Tune, 1969) of Figure 1 is that a high initial "Per cent Detection" corresponds to a fairly boring task -- the operator must respond to something that is easily sensed or observed. This type of task is most sensitive to a performance decrement with time. The more challenging task, the one where there is a smaller probability of detection, seems less sensitive to the time decrement.

In investigations of particular vigilance tasks where performance did deteriorate with time, Bergum and Lehr (1962) demonstrated a great improvement in detection performance over a 90 minute interval when the interval was broken into three 30 minute segments by ten minute rest periods. Bevan, Avant, and Lankford (1967) provided similar intervals, but allowed only five minute rest periods during which subjects either (1) engaged in vigorous physical exercise; (2) solved anagrams; or were (3) subjected to sensory restriction. All three of these experimental groups performed the vigilance task at a high level with no decrement throughout.

Thus, in the case of unchallenging (this may be an extremely easy task, or possibly a search for such a rare object that it no longer represents a challenge) vigilance tasks it appears that the best human performance will be achieved by providing some opportunity for operator "recovery" about every 30 minutes.

This period of 30 minutes seems relatively well established in the literature. Meloy (1970) questioned whether a more open-ended arrangement would improve performance. That is, would it be desirable to offer as an incentive the possibility of early release from watch if a certain level of performance (detection rate) could be achieved in an early portion of the watch? Although Meloy's finding is highly dependent upon the nature of his particular experiment, he could find no significant difference in either probability of detection or false alarm rate when this incentive was added. In other circumstances discussed in Section IV, goal specificity has been found to be a significant factor which can produce performance gains.

3. Temperature Effects

As early as 1940 the British Industrial Health Research Board (Chapanis, and others, 1947) determined that people differed a lot in what they thought was a comfortable environment (!), but found the following temperatures and ventilation seemed to suit the average person:

1. For very light work in the winter the best average temperature is about 65° F.

2. For active, light work in the winter from 60-65° F.

3. For work involving more muscular exertion in the winter from 55-60° F.

In hot weather, "the temperature should be kept as low as possible by thorough ventilation. The supply of fresh air should not be less than about 1,000 cubic feet per person per hour and should preferably be greater. In winter the rate of air movement should be about 20 to 40 feet per minute, and in warm weather higher velocities are desirable. The relative humidity should not generally exceed 70% and should be less if possible."

These are the general requirements for an environment which will make the average person feel comfortable; refinement but little change is reflected in more recent engineering handbooks (American Society of Heating and Ventilating Engineers, 1953). Figure 2 presents data from Mackworth (1946) which indicates that the temperature at which man can work if required without any loss in efficiency may differ from his subjective feelings about what's most comfortable.

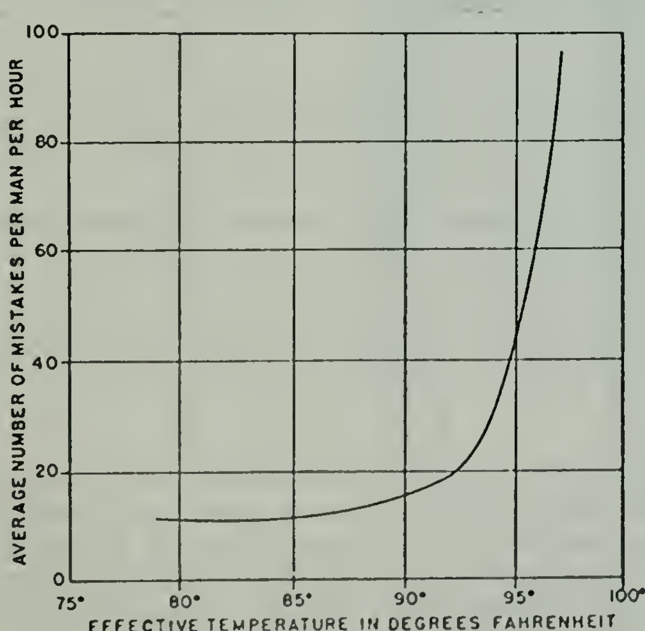

FIGURE 2 Average Number of Mistakes Per Man Per Hour vs. Effective Temperature in a vigilance (monitoring) task.

Effective temperature is an index which combines into a single value the effect of temperature, humidity, and air movement on the sensation of warmth or cold felt by the human body (See Table 1 for representative relationships). The numerical value is that of the temperature of still, saturated air which would induce an indentical sensation. Although Figure 1 does not indicate what would happen at effective temperatures below about 78° F., it has been found through later research that as temperature is reduced below 50° F., precision of hand and finger movements is reduced; however there are no materially adverse effects on so-called mental activities even at temperatures below 0° F. (Encyclopedia Britannica, 1967).

TEMPERATURE Dry /Wet Bulb / Bulb	RELATIVE HUMIDITY (30 In. Hg)	AIR VELOCITY (Ft. per min.) 20 fpm.	300 fpm.	600 fpm.
60/60	100	60°F	51°F	47°F
60/50	48	57.5	50	47
60/40	5	56	50	47
70/70	100	70	64	60
70/60	55	66.5	61	58
70/50	19	64	59	57
80/80	100	80	75	72
80/70	61	75	71	69
80/60	29	71.5	68	66
80/50	3	68.5	66	65
90/90	100	90	87	85
90/80	65	84	81	79
90/70	36	79.5	77	75
90/60	13	75.5	73.5	72

TABLE 1. Effective Temperatures and Relative Humidity for Various Conditions of Air Velocity, Dry Bulb Temperature, and Wet Bulb Temperature (Degrees Fahrenheit). Table developed from data contained in American Society of Heating and Ventilating Engineers (1953), and Weather Bureau (1941). (See Manual For Ship's Surface Weather Observations, OPNAV INST P3140.37 for additional relative humidity values.)

Present U.S. Navy Heating/Ventilating/Humidity standards (MIL-STD-1472A) require:

1. Maintenance of the interior dry bulb temperature at 68°F.

2. Ventilation at a minimum of 30 cubic feet per minute per man, two-thirds of which should be outside air. Air velocity shall be less than 100 feet per minute, and less than 65 feet per minute if possible.

3. Humidity values should approximate 45 per cent relative humidity at 70°F. This value should decrease with rising temperatures, but should remain above 15 per cent to prevent irritation and drying of body tissues (eyes, skin, respiratory tract).

For these standards, the values corresponding to Table 1 would be:

TEMPERATURE Dry/Wet	HUMIDITY (30 In. Hg)	AIR VELOCITY 65 fpm.	100 fpm.
68/56	45	63.5°F	62°F
68/47.5	15	61.5	60
70/57.5	45	65	64
70/49	15	63	62

4. Warmth-Fatigue Differences

Pepler (1959) examined a possible relationship between fatigue and warmth of surroundings. Evidence was sought on whether environmental warmth and a moderate sleep loss would have the same kind of effects on radar operator performance. Following analysis Pepler concluded:

1. Both conditions increased alignment errors in tracking and gaps in serial response.

2. Following sleep loss (one night deprivation), subjects tended to omit responses on the serial-choice task, and not to correct their increased misalignments in tracking.

3. In the warmth the same men did at least continue to respond to both the tasks, but their attempts were less successful.

These qualitative differences between the effects of environmental warmth and lack of sleep suggested to Pepler the generalization that: "Warmth reduces accuracy; sleep loss reduces activity." Although sleep is often subjectively associated with warmth, it appears from this study that the two are unique factors which have different effects on performance. Although the degree of fatigue suffered by a particular radar operator is often beyond the control of the Commanding Officer, the temperature of his environment is not. Maintenance of a cool CIC is recommended.

5. <u>End-Spurt Effect</u>

Another factor contributing to vigilance over which the Commanding Officer frequently has some control is the "End-spurt" effect. An experiment performed by Bergum and Lehr (1963a)demonstrated that in a vigilance situation where subjects had knowledge of time remaining in the vigil, their performance was superior to subjects who did not. Based on this result, duration-of-search information should be disseminated whenever it is available. Withholding such information may have a deleterious effect on search efficiency.

6. <u>Heavy Meals</u>

Certain "heavy meals" such as spaghetti or other pasta favorites seem to possess almost soporific qualities. The effect of no meal, of a standard meal, and of a high-fat

or high-carbohydrate meal, on the visual performance and fatigue of individuals was studied by Simonson, Brozek, and Keys (1948). Performance measures included the ability to carry out an inspection task, and visual testing. Subjective questionnaires were completed to provide a measure of subject discomfort. The analysis of results showed that no one type of meal was optimal for all functions; performance was poorest after the high-carbohydrate meal, but the subjective discomfort was least. The standard meal was preferable for the majority of the visual functions. Although short term performance gains might occur as a result of scheduling a high-fat meal, or avoiding a high-carbohydrate favorite; individual crew-preference considerations and the need to achieve a long term balanced menu at reasonable cost would frustrate any long term attempts to improve performance by diet alone.

B. SEARCH PROCEDURES

1. Discussion

This Section tacitly assumes that the operator is vigilant and knows that in a matter of seconds he will be expected to respond to a radar contact to the best of his ability. It is also assumed that the radar is optimally maintained, although certain operator adjustments may be required and are discussed below. The factors which can be used to achieve the optimal performance from the radar system can be categorized:

1. Awareness of propagation anomalies which generate false or missed contacts. This is such a well publicized part of the sonar problem that similar effects on radar systems are often overlooked. The operator's performance will be better if he is not "penalized" for errors properly attributable to anomalous propagation (False contacts and their relationship to operator performance are discussed in Section IV.).

2. Radar adjustments and external factors controlled by the operator.

3. Search techniques to be used by the radar operator or combinations of operators to improve detection performance.

2. Anomalous Radar Propagation

The problems caused by anomalous radar propagation are often incorrectly attributed to operator or equipment malfunctions. The fact that the problem may even disappear after the operator or Electronic Technician makes a few adjustments further supports the initial (incorrect) diagnosis. The problems of anomalous radar propagation are often short lived, or completely undetected; and information regarding the nature of the problem attracts little interest and receives even less dissemination. Sherar and Rosenthal (1973) provide a very complete discussion of this phenomenon which has been slightly rearranged and condensed in the following pages:

"Anomalous propagation of radar energy -- commonly referred to as AP or simply as radar refraction problems -- is a serious concern to the Fleet but one that is not likely to be satisfactorily solved in the near future.

"A number of factors can complicate the radar coverage pattern on a given day. These include such items as equipment, operator, and calibration problems, as well as a host of environmental factors such as reflection, refraction, diffraction, and scattering. Birds can sometimes cause distinct unexpected returns. Over oceanic regions, such phenomena as sea clutter can drown out all other sea surface

targets on a windy day; multipath (receiving of both a direct and sea-reflected ray) can cause gaps in elevation coverage. But one of the most significant phenomena of all when considering anomalous propagation and ghosts is the process of refraction.

"Refraction is the process in which energy rays are bent, because of changes in their velocity of propagation, caused by the ray's travel through mediums of varying density and composition.

"As early as World War II, the importance of refraction to the propagation of radar energy was widely recognized. It was observed that one radar would be able to pick up targets far beyond the normal radar horizon while, at other times, a radar could not detect an object which could be clearly seen visually. Possibly the most distant surface targets ever detected by radar were points on the Arabian peninsula seen from a 1.5 meter radar at Bombay, India, during the dry season -- a distance of about 1,500 miles. During the wet monsoon season, the same radar had difficulty seeing surface vessels only 20 miles away.

"The actual radar coverage pattern obtained at a given time has as much to do with the "geometry" of the situation as it does with the refractive index variations. The angle at which radar energy intersects a refractive layer determines the future course of the beam. Radar energy beamed at angles greater than five degrees is bent in a generally normal, gentle manner regardless of the refractive condition of the atmosphere and produces expected coverage and detection. On the other hand, radar energy beamed at very small angles to the horizontal (especially near one degree or less) can, in the presence of very strong refractive layers, be channeled, trapped, or ducted parallel to the earth's surface and be propagated far beyond the normal radar horizon. Such layers act as natural "wave guides," channelling and constricting radar energy and frequently leading to the detection of targets at ranges that would otherwise be beyond the radar's capability.

"In between, there may be a wedge of air space remaining which is essentially void or at least very deficient of radar illumination. This "radar hole" -- is an aberrational air space within a region of expected normal radar coverage, which, owing to strong refractive layers, is not illuminated by a radar at small look angles. Thus, a radar scanning the skies during routine tracking or special naval encounters may be plagued or enhanced by both holes and ducts.

"Of special importance to ship radars, in addition to strong, elevated layers, is a feature termed the "evaporative duct." This is a region approximately 30 to 90 feet thick

at its maximum, resting on the surface of large bodies of water in which the refractive index decreases so rapidly with height that low angle radar energy may be substantially trapped. The resultant duct is caused by the rapid decrease of moisture in the first few tens of feet above the water surface and is directly related to the difference in temperature between the sea surface and the air immediately above, as well as the air's local humidity and wind characteristics. Unlike the elevated layers there is no distinct "top" to the duct. The evaporative layers can produce greatly extended ranges for shipboard surface search radars whose antennas are situated within the duct and pointed at very small elevation angles. However, since the shallow evaporative duct typically does not extend as high as a ship's superstructure, ship's radars may be above this region and unable to take advantage of its potential for extended range as they look down into it. Thus, with a strong evaporative duct, it is possible for a submarine to pick up distant ships which cannot see the submarine because of both the size of the submarine target and the fact that ship radars may be above the duct. If both submarine and ship radars are located within a strong evaporative duct, it might be possible for both of them to detect distant incoming fliers or missiles also located within the duct, just skimming above the water's surface (assuming a low Sea State).

"The importance of the evaporative duct to the Navy lies not only in its potential ability to propagate energy from surface radars well beyond the normal horizon but also as a possible mechanism for explaining some of the mysterious unverified returns known as ghosts. There is a continuing controversy over whether these puzzling apparitions can be explained by low, strong elevated ducts, by irregularities in space of the evaporative duct, or by low-flying birds. Hopefully, probing of the evaporative duct by scientists will determine if there is any such ghostly influence ..."

There are other factors related to the refraction problem. "For instance, some atmospheric irregularities not detectable visually can cause backscatter from refractive interfaces large enough to produce detectable signals on a radar scope. This is often the source of "weather clutter" when no storms or clouds are present ..." Another is radar frequency, "for thin surface ducts, as the radar frequency is lowered, an increasingly greater change in refractive index between the surface and the duct top is required for trapping to occur."

"Occasionally, a process called multipath may cause an added confusion factor to the evaluation of radar coverage and the identification of ghosts. Multipath occurs when there are two signals returned from a target, a direct one

and a bounced or sea-reflected one. If the path of a target causes a land mass or island temporarily to come between the target and the radar, the reflected signal may be interrupted leading to drastic changes in radar range, and the target may disappear. This may lead to the erroneous conclusion that the radar had been tracking a ghost when the target was real. But while the importance of these other factors should not be minimized as they relate to the overall refraction and radar coverage problem in the atmosphere, the structuring and layering of the atmosphere itself remains the greatest concern when discussing refraction. It is the factor which often causes today's radar coverage to appear normal and tomorrow's radar coverage to seem like a complete mystery.

"What type of atmospheric or weather conditions distinguishes the days having standard refraction from the days which produce anomalous propagation, radar holes, and trapping? And which ones appear to favor ghosts?

"It might seem paradoxical for the most troublesome radar weather to occur in what otherwise appears to be perfect operating weather, but this is not at all inconsistent with atmospheric theory or observation. The reason is that clear weather is frequently associated with the eastern side of vast high pressure regions in the lower and middle atmosphere which produce a subsiding flow of dry air. This downward moving dry air precludes thick convective cloud formations which might lead to rain and inclement weather, and produces a warming and drying out of the air. The net result is a warm, dry air mass overlaying a shallow, cool, and -- if over water as off the California coast -- relatively moist layer just above the surface. If one progressed upward through these two different air masses, he would find that the moisture dropped rapidly with height and the temperature increased with height through the inversion. At the same time, he would observe a very strong super-refractive gradient. Sometimes, the shallow cool marine layer contains fog or low stratus clouds. Near islands and land areas, warming by the sun and local wind effects evaporate this thin cloud layer, typically resulting in a clear sky by midday. Undetected by human eyes, however, is the residual presence of a very strong super-refractive layer and potential disaster for the unsuspecting force commander in that area. Over much of the Mediterranean and probably regions like the Red Sea, the warmer waters and drier air above apparently preclude the low cloud formation so that the prevailing clear skies give no indication of the presence of refractive layers above the surface.

"Sometimes, the large-scale weather patterns combine with the small-scale evaporative conditions at the sea surface and form a single, exceptionally strong, surface-based, super-refractive layer that is deeper than the normal

evaporative duct. This occurs when strong subsiding flows of desert-dried or continental air flows across the coast and out over large bodies of water. Examples of such winds are sometimes dust laden khamsin winds of the eastern Mediterranean and the Mid-East and the often hot, dry Santa Ana winds of Southern California. In other parts of the world similar dry winds are known by such names as the bora near the Adriatic coast, the mistral along the southern French coast on the Mediterranean and the sirocco which blows across the North African coast. In all cases, very dry air flows out over the water for various distances causing great humidity decreases with height and sometimes sharp temperature inversions in the very low layers.

"These conditions -- which produce gaping radar holes for surface-to-air searches and strong ducts and extended range for surface-to-surface searches -- can present one of the most confusing radar coverage situations. While these dry winds lead to the most exceptional cases, it may be generally stated that any condition that results in a mass of dry air overlaying a moisture-ladden layer results in a strong super-refractive condition, with or without appreciable winds.

"In tropical and warm-water regions the absolute moisture content of the air is generally so high that relatively subtle changes in humidity are often sufficient to cause large changes...over very short distances. These may occur throughout the lower and midlevels of the atmosphere or very close to the surface, thus posing problems to both shipboard and airborne radar systems. It may be that such subtle and randomly spaced humidity and temperature gradients near the ocean surface are partially responsible for the ghosts and anomalous targets occasionally seen by radar.

"Over the warm waters in the northern Sea of Japan during cold, clear, low wind or calm nights, rising bubbles of warm moist air called thermals have been blamed as the cause of irregularities on the shape of the moon as observed visually from shipboard. On these same nights, the radars were also plagued by ghosts. Similar situations have been observed in the Mediterranean, in the North Sea, and off New England..."

"Moreover, some ghostly calls to general quarters can be attributed to birds. It is known that migratory waves of hundreds of birds returning to their roosts in harbors around the world can sometimes produce alarming radar returns.

"But there is still another important possible explanation of ghosts...the atmosphere does not really resemble the simplistic picture we want to assign to it. For instance, it is nearly always assumed in operational applications

that elevated inversions and super-refractive layers are flat and horizontally stratified. Yet, because of topographic features like islands and mountainous coastlines and numerous gravity wave-like disturbances in the atmosphere (which are very difficult to detect), the elevated layers are often wave-like and may exhibit height changes of hundreds of feet within distances of a few tens of miles or less. These waves, depending on their origin and the direction of the wind flow above and below, may move in any direction at various speeds and may exert a greater influence on propagation than the variations caused by large scale weather features, especially during stable, persistent periods or seasons.

"To the radarman watching his scope, bright blips may seem to approach his ship at high speed and, as quickly, disappear. Very subtle changes in the place and angle where the radar beam impinges upon the elevated super-refractive layer as it meanders in the wind flow may cause the returning signal to appear to jump, and may explain the sometimes unrealistically high speeds of these returns... To operational commanders in combat situations, the appearance of false targets closing in is no less alarming than real ones.

"With such pronounced effects on radars possible owing to refractive anomalies and layers in the atmosphere, it is natural to wonder how frequently these atmospheric conditions may be expected to occur. Unfortunately, there is little climatological information of this sort available and there is no known tabulation on the frequency of ghosts. There are, however, significant bits of data on refractive layers and ducting. Past reports by the APL (Johns Hopkins University Applied Physics Laboratory) have suggested that surface evaporative ducts occur approximately 80% to 90% of the time over subtropical and tropical oceans, especially in summer. Past reports from the NELC (Naval Electronics Laboratory Center) have estimated that surface trapping for X-band radars in the Near East and Southeast Asia because of the evaporative duct may occur 85% to 90% of the time.

"According to the APL reports, in colder climates, such as the North Sea, X-band ducting by evaporative ducts has been estimated to occur from 40% of the time in winter to 90% of the time in summer. Only in polar regions are ducts apparently infrequent, probably because of the very low duct heights and quite low values of absolute humidity despite the fact that evaporation rates are frequently high, particularly near the Siberian coastline. Current NELC efforts appear to point in general to a wide geographical and seasonal variation of this oceanic evaporative phenomenon.

"As for elevated trapping layers and ducts, apparently these, too, vary widely but can be very persistent in certain places of the world. Pacific Missile Range data taken at Point Magu in coastal Southern California indicate that elevated trapping layers could occur over 90% of the time in summer and well over 50% of the time in winter in that area. It is likely that similar high percentages will be found to occur over the Mediterranean also.

In the absence of refractive forecasts, meaningful conclusions about the likelihood of encountering anomalous propagation of radar energy can be developed by applying several simple thumb rules. Expect strong super-refractive layers to:

1. "Coincide with temperature inversions.

2. "Be present just above the tops of extensive decks of stratus or strocumulus clouds.

3. "Occur during warm, dry conditions over an open sea."

"In places such as the Mediterranean, the presence of cloudless skies, light surface winds and reports of warm dry air and high pressure extending over the operating area can be taken as forewarning of possible radar problems due to refraction. Over the eastern North Pacific Ocean, the presence of persistent stratus or statocumulus cover should be sufficient evidence of strong super-refractive conditions just above cloud tops in that region. Dry winds like the Santa Ana of Southern California and the Khamsin of the Eastern Mediterranean blowing over an oceanic surface are the atmosphere's warning of extreme super-refractive conditions at very low levels. And wherever strong low-level refractive layers and topographic obstacles to the wind flow appear together, mysterious ghosts might be anticipated."

3. Visibility vs. Detectability

Even with the most favorable environmental conditions a target will not be "seen" unless the signal presented on the operator's scope exceeds a certain detectability threshold. To be detectable the signal must first exceed the operator's visibility threshold. Baker (1962) makes the distinction clear:

"A visibility threshold refers to the signal voltage of a pip which can just be seen when the observer knows precisely at which part of the radar display to expect its appearance, e.g. he may be told to watch for a pip inside a quarter-inch square drawn on the scope. No visual search is involved. A detectability threshold, on the other hand, involves the factor of visual search: the observer is informed that the pip may appear anywhere on the scope. As would be expected, visibility thresholds are lower than (superior to) detectability thresholds."

4. Operator Adjustments

A request from the shipboard Electronics Technician to "Take a ringtime" (Radarman, 1969) conjures up in the minds of many some thought that by so doing we are insured, at least for a short while, that the radar is optimally adjusted and that the operator is being presented with the best possible display the set is capable of providing. This thought is erroneous; worse yet, most repeaters are incorrectly adjusted by the operator himself with a resultant signal loss of as much as 20 dB from incorrect brightness (Baker, 1962), and another 17½ dB from incorrect focus (Williams, 1949).

For specific radar's, the applicable Operating Procedures Technical Manual may provide adequate information so that the optimum detectible signal at the scope face can be obtained. Such procedures should be adopted. Scope brightness is adjusted by rotating the intensity or brilliance control (CRT Bias Adjust) on a radar console -- operational radar scopes are often set at a brightness which renders the sweepline just visible. In some cases a penalty of 20 dB is paid by operating at visual reference, and this results in a range loss of 40%. On a circular cathode ray tube (CRT),

this amounts to about 65% of possible radar coverage (Thornton, 1956). There is a gradient of scope brightness in the radial dimension on a CRT: brightness is highest near center and decreases at the periphery. Because of this, optimum brightness should be made with reference to that radial position which is of greatest importance -- in the case of early warning radar for example optimum brightness should be set near the periphery of the scope. Whenever the range scale is changed, scope brightness changes, and should be reset to restore optimum brightness. The optimum level also changes with age of the CRT. Noise level is also related to the optimum brightness level. For example, increasing bias to adjust brightness adds to the size and number of noise spots, which in turn adds to scope brightness. If noise level changes, this will change brightness levels. In some cases target detectability might actually be improved by increasing the noise background (Baker, 1962). The following procedure, from Baker, while applicable to a specific radar equipment, illustrates quite well the care that must be taken to obtain optimum noise and bias (brightness) levels in an operational environment. It may be obvious why the less effective but simpler visual reference setting has so many proponents.

"DEMONSTRATING OPTIMUM SCOPE BRIGHTNESS

"The phenomenon of optimum scope brightness is simple to demonstrate in any setting where a pip is just visible on a scope of optimum brightness. By simply rotating the brilliance control so as to achieve a darker scope the pip will disappear, and then reappear when the optimum brightness is reinstated.

"SETTING OPTIMUM SCOPE BRIGHTNESS

"One manual of operational radar procedures on our desk states, under Adjustment of Controls, that "the PPI should be adjusted to the most sensitive setting for detection at maximum range". Apparently this adjustment is a matter of operator opinion and it is simple to demonstrate that there are as many opinions as there are operators. Williams and King (1946) cite operator instructions which, while being quite specific, are wrong: "Adjust intensity until the sweep trace is just visible on the scope, when the IF gain is set at minimum".

"What is needed is a technique for setting optimum brightness which (a) is accurate, (b) results in the same settings being made over long periods of time by the same operator, (c) results in the same setting being made by different operators, and (d) is simple to use. Obviously one could employ a voltmeter, if one knew the grid voltage appropriate for each individual CRT and how it changed with age. A photometer might be used if the correct brightness values were known. One might also use a target generator to generate a standard pip which was visible only when optimum scope brightness prevailed. These are not simple solutions.

"An acceptable technique has been demonstrated by Machen et al. (1956). The human eye is not a reliable device for estimating absolute brightness, but it is remarkably precise when making threshold judgments. Advantage is taken of this fact by placing a glass filter of neutral density, 4 inches square, over a portion of the scope and having operators adjust scope brightness until the sweep-line is just visible through the filter. This they can do within +/- .5V of grid bias. The filter is then removed and the scope is at optimum brightness. The theoretical density for such a filter is 3.15. For practical purposes any filter having a density from 3.0 to 3.3 is adequate. These characteristics for an appropriate filter were first determined for CRTs having a P7 phosphor (yellow with blue flash). It is now known (Smith and Boyes, 1957) that the same filter density is correct for a P19 magnesium fluoride screen (red-orange). The filter technique can be used also for setting the correct noise level, as described in the next section.

"PROCEDURE FOR SETTING NOISE AND BRIGHTNESS WITH FILTERS

"The following detailed procedure has been described by Smith (1956) for FPS-3 radar equipment, which is commonly employed in an early-warning role. It is not known whether modification of this procedure would be necessary for other equipments.

"A. To Adjust Noise Level
1. With no filter in place and with video and all other sources of noise switched off, adjust brightness until the sweep-line is just visible.

2. Place a neutral filter (4X4 in) of density 4.0 (mounted in a convenient mask if desired) over the tube face. Turn the video on, and increase the video gain until the noisy sweep-line, i.e. that portion beyond local clutter and away from permanent echoes, is just visible through the filter.
3. Leave video gain control in this position.

"B. To Adjust Optimal Bias (always after adjusting noise level)
1. Replace the filter mentioned above with one of density 3.0 to 3.3.
2. With video switch off, but gain control still at the setting determined in A, adjust brightness until the noise-free sweep-line is just visible through the filter. Leave the brightness control at this setting.
3. Remove filter and turn on the necessary operating switches.

"Unless major changes in range, etc., take place, no further adjustment to the brightness or gain control should be made.

"In the absence of a filter for setting the noise level it is recommended that optimum screen brightness be set with a filter of density 3.0, with no noise. Video can then be turned on full.

"OPERATIONAL TESTS USING OPTIMUM SCOPE BRIGHTNESS

"Bessey and Machen (1957) performed an experiment in an operational radar station, using normal air traffic. In one room -- the bright room -- (illumination of 0.1 ft-c at the scope face), scope brightness was optimum. The other room -- the dark room - scope brightness was at visual reference. The results follow:

"1. 19.2 per cent more plots were recorded in the bright room than in the dark room. The probability of this difference occuring by chance is less than one in 1,000.

"2. Tracks 20 miles or more in length were analyzed. There were 70 of these. All 70 were recorded in the bright room. In the dark room three were never recorded, 10 were recorded as one plot only, and 18 were tracked for less than 20 miles.

"3. Concerning earliness of initial detection, the bright room was superior to the darm room on 50 tracks, the same on 19, and inferior on one.

"4. In the bright room targets were tracked further in 43 cases, the same distance on 26, and less on one.

"5. Continuity of tracking (fewer gaps) was superior in the bright room in 13 cases, and the same in 57 cases.

"6. The advantage in earliness of "early warning" was computed to average 34 miles in favour of the bright room."

Three-inch neutral density gelatin square filters are available in camera stores, and can be used to obtain optimal noise level and brightness adjustments in a manner similar to that described. Where the exact filter density required is not available, it is a simple matter to "build" the proper filter. Filters of .1, .2, and 3.0 can be sandwiched for instance to obtain a 3.3 filter.

There are additional variables which will be mentioned briefly. Gain: Smith and Hunt (1957), using operational equipment, found that "In general, the higher the gain -- and hence the noise level -- the better is target visibility at all CRT biases." Focus: Williams (1949) found that with a dim scope, operated at visual reference, extreme defocusing resulted in a loss of only one dB in the visibility threshold. At optimum brightness, however, the loss was 10½ dB, while at extreme brightness the loss was 17½ dB. He also demonstrated that the "best focus" set by an operator yielded thresholds which were within 1 dB of those obtained with the focus which actually was best in terms of visibility, at any scope brightness.

5. Ambient Illumination for Scope Visibility (Generally from Baker, 1962)

As a general rule, some light in a radar room would be beneficial if minimum target visibility thresholds are desired -- the brighter the scope the greater the amount of

ambient illumination needed. Ambient illumination levels about equal to that of the eye's central field (angle within about one degree of fixation point) give an advantage over total darkness of about ½ dB. As illumination increases, the scope will tend to be "washed out," and visibility diminishes rapidly. At moderate and high levels of illumination, blue permits target visibility thresholds significantly superior to that of other colors; at lower illumination levels the difference is less significant. Under blue illumination, the maximum target visibility threshold occurs at a low level (.1 foot-candle), and is slightly less at levels either greater or less than this value.

6. Optimal Eye Scan

The final element necessary for target detection is a successful search by the radar operator. If the operator searches inefficiently or incompletely, needless system degradation will occur. The Naval Tactical Data System (NTDS) may unfortunately reinforce inefficient or careless operator search, since the omissions of one operator can be compensated for by the satisfactory or overlapping performance of another (Lockee, 1969). Even with NTDS, though, we are often required to search without backup: the surface search console operator often functions alone, and during times of low air activity a single air search console might be manned. Any person searching a cathode ray tube for information -- the OOD, sonarman, ECM Operator, and others, might do so more effectively with an understanding of the basic principles

of search presented here. This discussion is directly applicable to the planning position indicator (PPI) display most commonly found aboard ship.

Development of a satisfactory technique for monitoring individual eye scan patterns has made it possible to study visual search characteristics under conditions approaching those found in the real world. This technique is electro-oculography (EOG), and one of the earliest applied studies using this procedure was conducted by White & Ford (1960a). Findings indicate that during search, the operator tends to follow along behind the scan-line by means of closely spaced fixations, with the pattern being randomly interrupted by jumps of varying magnitude in and out along the scan line. During the time between these jumps, he tends to remain focused on about the middle of the scan line, regardless of the size of the display. The distribution of the jumps is fairly symmetrical with the outward jumps occurring about as often as the inward jumps, and covering the same average radial distance. The average fixation time is .37 seconds. We will see (In Section V.) that under normal vision, perception is sharpest at the point of fixation. Craik and Macpherson (1945) determined that for a radar return, the visibility threshold deteriorates linearly by about 5 dB, as the angular distance of pip from fixation point increases from zero degrees to 15 degrees. Beyond 15 degrees, the rate of deterioration increases rapidly. The net effect of these two phenomenon is to confine our area of effective

search at or near half-range, and to effectively exclude those areas near the periphery or sweep-line origin from search. Baker (1962) hypothesizes that the consequences of this basically back-and-forth search technique apply in searching a horizon for ships or in searching a microscope field. As an example of a practical situation where a conscientious effort is made to overcome this inefficiency, he cites the case of students being taught to study X-ray photographs who are exhorted to "pay attention to the outside, the center will take care of itself."

Other studies (Wallis and Samuel, 1961; Colquhoun, 1961) confirm this basically circular search pattern with the tendency to view the inner portion of the display more closely than appropriate. Other generalizations are frequently made in laboratory studies such as: (1) "There was a considerable amount of time spent looking away from the display," or (2) "As the operator becomes tired his fixation rate slows, and he begins to stare for longer and longer periods at the center of the scope, or some irrelevant aspect of the display," or (3) "Operators will be unlikely to cope effectively if there are as many as 10 contacts to be watched simultaneously on the display," or (4) "Some amount of irrelevant information such as old targets, jamming, or clutter is beneficial and helps to maintain operator alertness during continuous activity." Often, two or more of these generalizations may be drawn from the same study. Less scenario dependent and perhaps most significant are these general findings:

1. During actual watchkeeping sessions, the differences between operators in their ability to detect targets may be partly attributable to differences in ability to search the display effectively, rather than to differences in general alertness or vigilance (Wallis and Samuel, 1961).

2. To date, attempts to improve target detection proficiencies under laboratory simulations by providing special training, using groups of experienced radar operators, or practice, have been disappointing (Wright, Frederickson, and Claflin, 1964). Baker (1962) cited a large body of available data on selection and training of radar operators and concluded: "Although I consider this research area a valid academic exercise, the practical rewards to date are disappointing."

It can be observed that the special training technique in the Wright, Frederickson, and Claflin experiment did not include instructions on scanning techniques, and this may have been critical.

In theory, uniform distribution of search over the radius of the display can be obtained by continually sweeping your eyes along behind the rotating scan-line, in a consistent direction (for example, from the center of the scope to the periphery). Although this technique might have a certain practical appeal, the result would be to concentrate the search at the center of the scope since the area searched is a function of the radius squared. In some situations, this type of search might be desired. A regular back-and-forth sweep behind the scan line concentrates the fixations and the search at about mid-range. If concentration at a particular range _is_ desired, this could be achieved by inscribing a reference circle at that range (with grease-pencil for example) for the eyes to return to between fixations and a back-and-forth sweep behind the scan-line. To

improve early warning performance, the central portion of the radar could be masked out; or the operator may be able to concentrate his attention at the end point of the rotating scan-line once he is aware of the phenomenon of peripheral blindness and its causes. In operational situations such concentration probably does occur in principle, since the operator will tend to favor an area or direction in which new contacts are most likely. The presence on the scope display of land, other forces involved in the radar search, and "areas of interest" complicates the operators usual scan pattern. Further, the operator has some feeling about where the next target is likely to appear (the appearance of a contact at any point on the display with uniform probability is a creation of the laboratory and not of nature) and this too modifies his sweep pattern. Baker (1958), by masking parts of a radar display, has demonstrated that with operator concentration deliberately focused on a particular part of the display, detection performance in that area can be improved.

7. Conclusion

The conclusions from these various studies show that the visual search technique of the radar operator is an important element in overall radar system performance. The operator can conscientiously control his scan pattern to a great degree (Nicely and Miller, 1957), and he can devise temporary lines or overlays to assist him in obtaining efficient scan. The more information he has about where to

look, the better he can tailor his search to the task. This does require premeditation: thought about how the eyes should be moved, and then concentration in carrying out the plan. Moving the eyes like a broom, to keep dust or falling rain from a certain area, might be a useful visualization to help in achieving a more "patterned search." A "random search" consistently favors particular portions of the display to the exclusion of others, and the greater the operator's fatigue the more extreme the bias. To search effectively requires a master plan — this is as true in the case of a radar operator sitting at his console as it is of the ship itself, searching in some prescribed "Expanding Square."

IV. SONAR OPERATOR

A. TRADITIONAL CRITICISMS

> "The combination of a highly specialized hardware subsystem results in an ASW system with performance limited not by hardware capabilities but the human understanding of those capabilities."
>
> Lt. R.L. Brandenburg
> (Brandenburg, 1964)

> "Significant improvement in ASW readiness and systems performance is achievable if we are willing to make an investment in the upgrading of the human element in these systems."
>
> Robert R. Mackie
> (Mackie, 1972)

The case for training, improved individual qualification, minimum performance standards, and better design has been eloquently pleaded through numerous forums. The basic premise of these arguments is that improvement in surface ship ASW performance is urgently needed, and once this "fact" is established a thesis is developed which recommends certain actions to reach that objective. Some unmentioned cost is associated with each of these actions, but this cost is either ignored or assumed to be less than the benefit.

While improving surface ship ASW readiness has a certain patriotic quality, it may just be that from the standpoint of this nation's overall broad national objectives and commitments the additional dollar spent for surface ASW will not buy us as much as the same dollar spent elsewhere. If "no cost" performancegains are sought, then we must concentrate on using what we have more effectively.

B. INDISTINGUISHABLE DOPPLER

"Sonarmen don't have the ears they used to!"

Anonymous Member
Ship's ASW Attack Team
Condition 1AS

Maybe so, but they don't have the equipment they used to have, either. Not only must the sonar operator's auditory threshold be low enough to perceive the "faint echo," but once the engagement is joined he is expected to report changes in pitch caused by the target's motion in the line-of-sound (LOS) relative to the surrounding reverberating medium. Old sonar texts, and obsolete fleet school doctrines often emphasize the importance of combining doppler information from the sonar operator with other fire control and CIC solutions to "solve" the attack problem. Not emphasized is that with today's low frequency sonars, doppler shifts simply can not be detected by audio means.

Sonar Operating Frequency (KHz.)	Target Speed in LOS required for 100 Hz. doppler shift
30 KHz.	5 Kt.
5 KHz.	30 Kt.
3.5 KHz.	42.8 Kt.

For a given target speed in the LOS, the magnitude of the doppler shift is inversely proportional to the operating frequency of the sonar (Urick, 1967). As the data above dramatically illustrates, doppler discrimination with older, higher frequency, sonars is greatly facilitated. The 100 Hz. doppler shift is an arbitrarily chosen value, but target

doppler shift and target speed in LOS are directly proportional so that other relationships can be formed easily. Actual sonar operators have been found to be 95 per cent accurate in perceiving doppler shifts of 25 Hz., and 50 per cent accurate for ten Hz. shifts (O'Hanlon, Schmidt, and Baker, 1966). The problem of doppler discrimination is actually most acute with slightly older sonar systems -- the most modern electronically determine doppler, and the "discrimination" required by the operator consists of reading a value from the face of a meter. Unfortunately, the large majority of operational systems today do not have this feature; and in a scene re-enacted all too frequently, the sonar operator is required to make a report which is at best meaningless (i.e., "no doppler"), and at worst no more than a guess (i.e., "up", or "down" doppler). More often than not, this report will be based on target aspect and relative motion as determined by the operator from the face of the scope with a grease-pencil, and unless this fact is known to Command or the OOD, the report can be highly misleading. This rather lengthy preamble introduces a factor which is pre-eminent in the mind of the sonar watchstander.

C. FALSE CONTACTS AND MOTIVATION

The sonarman wants to do a good job as an individual, and as a member of a select group he wants to establish himself as professionally competent. Not an easy task for a sonarman, especially when performance has such low visibility. 99.9 Per cent of the time he is on watch, he has

nothing to report. Often his sole opportunity for recognition, and his reputation, are based on what he does (or does not do) during the other .1 per cent of the time. If during this brief moment of recognition he's asked for "doppler," he'll find a way to report it. Similarly, if he senses disappointment or disapproval when he makes a report which is later determined to be a "false contact," it is certain that the next time he will not make the report quite as soon. For him, the penalty for making a false report is often greater than that received for failing to detect a true contact.

The choice the operator makes between avoidance of a false contact and the possibility of failing to detect a true contact has been variously investigated, and results support the contention that detection performance can be regarded as a decision task (Evans, 1965). Weiner (1962; 1963; 1964,a) in a long series of experiments extending over several years investigated the factor of "cost" in the response of individuals to various signals. Weiner found that by awarding "points" as a reinforcement for correct responses, or by deducting points for errors, he could manipulate observed operator performance in vigilance tasks. Broadbent and Gregory (1963) performed a number of experiments in which subjects kept watch during long periods for inconspicuous signals. They found that detection responses

"are quite inconsistent with the concept that stimuli are either definitely perceived or definitely fail to be detected, with no intermediate category. The results are more consistent

with a model of perception as the outcome of a statistical decision made with more or less caution ..."

Colquhoun (1967) in a vigilance task which simulated sonar target detection compared performance for operators instructed to report only targets they were sure of (SURE) with performance in later sessions where they were instructed to report any signal-like sound (UNSURE). Colquhoun found:

> "a substantially higher percentage of both "weak" and "strong" signals was detected with the UNSURE procedure. False report rate was also higher with the UNSURE procedure, but analysis showed that this reflected a change in decision criterion rather than in discrimination efficiency.".

By varying the operator's risk and reward factors, various performance levels can be achieved. Even requiring him to keep a written log of his detections increases his conservatism: "he makes fewer false reports but, on the other hand, he misses more signals or allows them to persist longer before reporting them." (Howland, 1958). In fact, if the operator is told: "Never make a false contact," (i.e., probability of false detection will be 0) he will accomplish this by never reporting any contact and theoretically the detection probability of the system will necessarily drop to 0. The positive effect of rewards on performance has often been confirmed by experiment (Yufer, 1969; Smith, Lucaccini, and Epstein, 1967). Typical rewards include "points," "praise," or more tangibly early release from watch or money. In one famous instance at the height of the Cold War, a case of Johnny Walker Black Label Scotch was offered to the first ship that could detect and track a soviet submarine until she "surfaced." Apparently such

rewards tend to make the operator less risk-adverse, and increases in both actual target and false target detections should result.

D. RECEIVER OPERATING CHARACTERISTICS (ROC) CURVES

Empirical curves can be constructed for detection systems that illustrate the relationship between actual and false target detections. These curves can also be determined theoretically, and are valid for particular equipments detecting a steady signal, in a completely random noise background (Urick and Gaunaurd, 1972). An example of one such theoretical receiver operating characteristic (ROC) curve is shown in Figure 3.

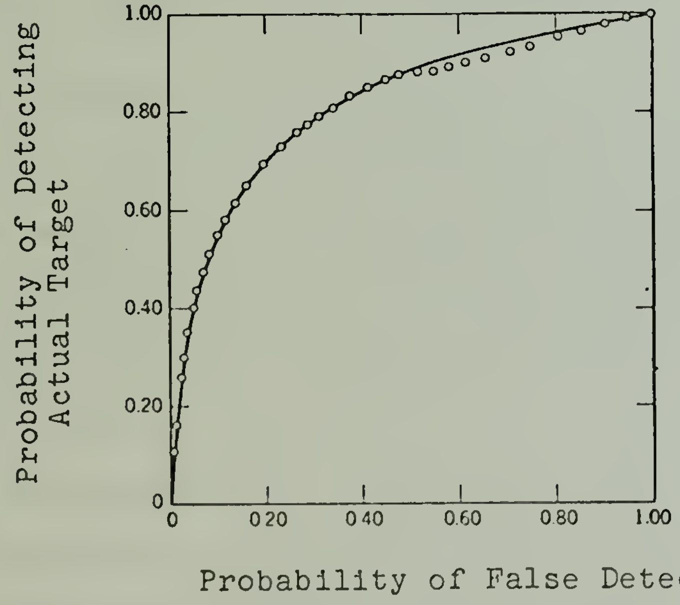

FIGURE 3 Typical ROC Curve (Green and Swets, 1966)

Varying the risk and reward factors change the point that we operate at on a particular ROC curve, but this does not change the shape of the curve (i.e., we might improve probability of detection, but our operating point simply slides up along the curve and we find that our probability of false contact is also greater). To change the shape of the ROC curve (to obtain a greater probability of detection with the same false alarm rate, or to obtain a lower false alarm rate with the same probability of detection), we must change the detection system itself (in practice, reward probably does increase vigilance and motivation, thereby changing the system and shape of the ROC curve). One method of changing the system involves improving operator performance through a technique known as "pairing."

E. PAIRING (MULTIPLE WATCHSTANDERS)

Pairing is using more than one observer, and in one of the earliest experiments studying detection improvements achieved by pairing, Schafer (1949) found significant improvements with multiple operators, but found "there is little to be gained by adding more than 2 extra observers." In a later experiment Morgan and Alluisi (1965) found that the paired operators were operationally "independent," and that the theoretical maximum increase in detection could be achieved. That is, if the probability of target detection for one operator has the value of .1, then by using two operators in the same situation the probability of detection increases to .19, three operators to .271. For illustration,

other values are shown below where the probability of detection by one operator is .5 and .9.

PROBABILITY OF DETECTION FOR INDEPENDENT OPERATORS

1-operator	2-operators	3-operators
.1	.19	.271
.5	.75	.875
.9	.99	.999

Independence certainly doesn't exist in the usual case, and other experiments conducted under different conditions have achieved less than the theoretical maximum gains (Bergum and Lehr, 1962,a; Ware, Baker, and Drucker, 1964). Under no conditions has the effect of pairing been adverse. Even where no clear improvement in detection probability is achieved, the mechanism of team consensus feedback (discussed later in this Section) will provide measurable training benefits. In that pairing requires additional watchstanders, it is not a condition which could be maintained indefinitely. However, when it is important to have absolutely the highest probability of detection possible over a rather short period of time, then pairing is rational. Baker (1962) cautions that

"no advantage of multiple operation can be expected unless each operator searches actively and continuously. The writer, and probably the reader, is familiar with situations where doubling the number of operators results in halving the amount of work each does, by informal agreement between operators, i.e. "Today I'll watch and you read." Team behavior ... is undoubtedly a very potent factor in detection performance."

F. RESEARCH SUMMARY

In spite of a paucity of submarine target services, there seems to be no lack of experimental data upon which to base a few recommendations for improving shipboard sonar performance. Some of the more significant experimental findings related to the human factor in anti-submarine warfare (ASW) are listed below. Items 1-8 are from Baker and Harabedian (1962) and based on that organizations experiments with actual sonar operators and shipboard signal generating and processing equipment.

1. "In a situation such that virtually all targets were detectable when the operator knew when and where to look, about 13 per cent fewer were detected when a target was known to be imminent, but had to be searched for.

2. "In a watchstanding situation lasting 45 minutes, when the operators knew neither when nor where a target would appear, some 20 per cent fewer targets were detected than when they knew that a target was imminent.

3. "When, at the end of a watchstanding session lasting 45 minutes, the operators were again alerted to the imminent appearance of targets, there was improvement in the efficiency with which they detected subsequent targets, but the improvement was not to that level of efficiency obtaining just prior to the watchstanding session: some "fatigue" is inferred.

4. "The decrement in detection performance during watchstanding sessions occurred and was complete within the first few minutes on watch.

5. "Efficiency of detection performance under conditions in which the operators were alerted to the imminent appearance of a target, was moderately indicative of that during a watchstanding session lasting 45 minutes. This finding suggests the possibility of a selection test for sonar operators (utilizing shipboard test set).

6. "With respect to consistency of target detection performance, operators were found to perform rather consistently within a watch, but not from one day to the next, nor from one experimental condition to the other. They were

consistent from day to day, and from condition to condition, however, in the frequency with which they made false reports of targets.

7. "Efficiency of detection performance was not related to target bearing, but was related to target range. Detection efficiency was superior for targets located near half-radius on the visual display.

8. "Efficiency in the detection of sonar targets was not found to be related to criteria of ASW school achievement or to scores on selected aptitude tests."

Mackie (1964) summarized the results of six years of research on human factor problems in ASW. While the specific document is classified, the general results were:

9. An average vigilance decrement (loss) of about 20 per cent occurs in the first few minutes of a sonar watch. The less frequently signals appear during the watch, the more severe the total vigilance decrement; when signal rates on a visual display are low, a variety of auditory stimuli reduces the vigilance decrement. The audio decrement over time appears to be less than the visual decrement.

10. The introduction of artificial signals increases the probability of detecting infrequent real signals. The level of vigilance maintained by the operator is also a function of environmental stimulation from sources other than the detection displays. If the extra stimulation is not actually distracting, the added "arousal" it provides serves to facilitate vigilance.

11. Immediate knowledge of how well he is doing reduces the operator's vigilance decrement.

12. Operators expecting long intervals between signals are particularly prone to missing signals that occur soon after one that has been detected.

13. Vigilance decrements are less severe in complex monitoring situations than in simple ones although the absolute level of performance may be lower for the complex display.

14. Detection performance on redundant auditory and visual displays is superior to that on either display used alone. Operators monitoring more than one display are inclined to attend selectively to the display having the more easily recognizable signals. If the displays are not redundant, this can adversely affect detection probability.

15. Performance on vigilance tasks is not reliably predicted from scores on conventional psychological tests of aptitude, temperament or motivation. Traditional sensory threshold measures are only slightly predictive of vigilance performance.

16. Baker, C.H., Parker, and Rittger (1964) found that "by increasing the gain (actually decreasing the gain voltage by 3.3 volts) above that selected by operators of an AN/SQS-23A sonar operating at sea, target detection performance with respect to targets generated by the sonar test set was improved by 3 decibels."

17. Horton (1957): "Over a wide range of conditions it is safe to assume that the reduction in signal differential responsible for a reduction in the probability of successful observation from 90 per cent to 10 per cent will be in the neighborhood of 4 dB."

18. Neal (1967) determined that for an auditory vigilance task, pretask instructions can have a significant positive effect on the monitor's performance, at least in the short run.

19. Motowidlo, Loehr, and Dunnette (1972) investigated the relationship between an individuals work performance and the nature of the goals that are set. "When it is feasible to set specific goals, the goals should be set (by taking prior performance, ability and other "trait" factors into account) so that individuals' expectancies of success are high, and the work setting should provide feedback cues to confirm for them that they are indeed approaching their goals successfully. When, however, it is not feasible to set specific goals, the "management" of motivated performance may be considerably more complicated. Without specific goals, individuals apparently will perform best when they are somehow made to believe that goal attainment is neither too easy nor too difficult but somewhere in between. As should be apparent, performance toward specific goals may take greater advantage of individuals' expectancies based on their own prior performances, abilities, skills and other trait variables. In contrast, performance toward ambiguous goals will usually need to rely more heavily on situational variables and particular aspects of the work setting to develop the middle levels of state based expectancies likely to yield highest performance."

20. O'Hanlon, Schmidt, and Baker (1966) found no impairment in the ability of a sonar operator to discriminate doppler after listening to sonar returns for 90 minutes.

21. Bergum and Lehr (1963) studying the relationship between vigilance performance in a monitoring task and the

presence of superiors, found that a random visiting schedule by either a commissioned or noncommissioned officer greatly facilitated detection performance.

22. Wise (1967) studied the adverse effect of transfers, discharges, leave periods, and school assignments on ASW team performance. The percentage of valid detections, localizations, and attacks that the squadron averaged during both periods of enforced crew stability and normal crew turnover were recorded, compared, and statistically analyzed. The findings revealed significant differences across all phases. The conclusions were "that under conditions of typical crew turnover, the operational performance of the aircrew is significantly impaired, and that aircrew instability produces less valid detections, localizations, and attacks, as well as greater operator error, than occurs under conditions of enforced crew stability."

23. Baker, C.H. (1963) investigated sonar operator settings of bias and gain, and found that "sonar operators do not operate their displays at optimum values of bias and gain. Operation at optimum values of bias and gain should result in substantial improvements in detection performance." This study recommended several practical methods for setting optimum values. One method involved making a visual threshold determination of CRT brightness through an optical filter as was done in Section III. The second involved the use of the installed sonar test set and recommended making adjustments to maximize target thresholds. (A third method which may be applicable in some cases involves the use of a voltmeter to set optimum values as determined from correction factors to be applied as the CRT ages.)

24. Cockrell and Sadacca (1971) conducted a series of experiments over several years to develop and test the team consensus feedback method as a technique for maintaining and enhancing the proficiency of individuals in detection and classification vigilance tasks. The essential feature of the method is that individuals practice in teams, arriving at decisions with regard to target detection and identification by a consensus of the team members. The only feedback which the individuals receive with regard to the accuracy of their decisions they provide for themselves during team discussion and comparison. "The general conclusion from the four experiments is that the team consensus feedback is an effective method for maintaining and improving ... proficiency. Although precise feedback leads to greater learning, precise feedback is seldom available, especially in field situations.

"Overall results for the four experiments indicate that team consensus feedback practice leads to greater learning than individual practice in target detection and

identification. The method has been shown to be most effective in increasing identification proficiency. The team consensus feedback method was also effective in reducing number of false targets reported. Only with the most effective team procedures (Experiment IV, mentioned below) was there a significant increase in number of targets correctly detected.

"Team composition in terms of proficiency seems highly important in the team consensus feedback procedure. Where teams are heterogeneous in proficiency, learning is substantially greater than where teams are homogeneous in proficiency. This fact seems to indicate that team members learn more from each other, and unless at least one member of the team is more proficient than the others, very little learning will occur. This conclusion was clearly borne out in Experiment IV where the highly proficient (individuals) in the team practice groups learned only a small amount more than the control (individuals), whereas the (individuals) of medium and low proficiency learned much more than the control (individuals).

"The ideal procedure seems to be to have three-man teams whose members are heterogeneous in proficiency using the immediate consensus work procedure. In this procedure, all (individuals) first perform initial (classification) on an individual basis and then get together to decide on the team (classification). The crucial factors seem to be the individualized initial (classification) and the opportunity for immediate feedback through comparison of responses and discussion with teammates."

G. ADDITIONAL CONCLUSIONS

In many cases the findings above clearly suggest the optimum action. For other items some additional inferrences might be drawn and are listed below (numbers in parenthesis refer to the items above which tend to be supportive):

1. Since the decrement over time is greater for detecting rare targets than for detecting frequent ones, performance may be improved by increasing the number of targets which the operator must detect (9), and by introducing the powerful motivating force that a knowledge of results provides (Section VII; Baker, 1960a; Fitts and Posner, 1967). Because of the inherent limitations of most sonar target generators, due mostly to the inability to generate a signal of sufficient realism (Mackie and Harabedian, 1964), a very useful procedure would be to require the sonar operators to

report all real targets acquired -- surface ships and biologics alike. In spite of "doctrine" which requires such reports, the usual procedure is for the operator to track a contact for some time, and to obtain an informal report from CIC regarding the presence or absence of surface shipping, before he even considers making a report. If CIC or the lookout can add that the operator's contact is a surface ship, then often no report is made or even logged. An effort to foster an atmosphere where reports from sonar are not only desired, but encouraged, would be extremely beneficial. A side effect that the ship will realize from fuller integration of the sonar operator into the ship's usual detection "triangle" (Lookout, CIC, OOD) will be that under conditions of reduced visibility, contact information from sonar can be extremely helpful (sonar alone can immediately determine if a particular ship is underway or anchored). Under some circumstances such as periods of electronic silence or radar failure, sonar ranges might be the best information available for maneuvering purposes. Like reduced visibility plotting, unless the techniques are practiced under conditions where they might not really be necessary, they won't function well when they are vital.

2. Closely related to the benefits accrued through increasing target density is that obtained through introducing secondary or irrelevant stimulation. Typical experiments require the operator to be alert for some signal or change in a condition not related to his primary vigilance task, and are able to demonstrate that performance at the primary task is thereby enhanced (10; cf., Baker, 1966; Catalano, 1967; McGrath, 1960, 1965).

"The general conclusion ... is that knowledge that signals on a peripheral vigilance task will definitely occur is a factor which, at least early in a task, results in superior performance on a central vigilance task. When the peripheral signals do begin to occur, the high level of performance on the central task is maintained by knowledge of results about performance on a peripheral task."

"Initial activation level is achieved by the impact of the relatively new stimulation in the task situation together with the subjects internal state as a function of instructions and other motivating factors. After the first few minutes, there is no stimulation which has not been experienced recently; both the negative stimuli and the signals become familiar, and so do the kinesthetic and other stimuli associated with the subjects responses. As time goes on, the impact of these several types of stimuli declines gradually, contributing to a decline in the subjects level of activation. As activation sinks below the optimal range for the task, performance will suffer...Any factors which sustain the total impact of stimulation will sustain activation, and performance will be maintained...In principle, it

should be possible for subjects to maintain activation through the impact of mental sets or of muscular activity extraneous to but not interfering with the activity required for the task."

"A significantly greater percentage of signals were detected under conditions of variety auditory stimulation than under white noise conditions. The improvement under variety conditions was greatest during the last quarter hour of the watchstanding period."

"Performance on a vigilance display presenting easily detectable signals was shown to be enhanced by requiring the observer to monitor simultaneously another display, presenting difficult signals via a different sensory modality."

The effort here should be to provide "peripheral tasks" which will serve to improve the operator's primary task performance. Operation of a sonar tape or bearing time recorder, measuring noise and source levels, maintaining the contact log, obtaining bathythermograph information, briefing the OOD on acoustic conditions, and providing turn-count and target description information, could provide the desired stimulation. The OOD must be aware of the true conditions in sonar, and the attitude and sensitivities of the sonar watchstander(s) involved. If perceived by the watchstander as a form of harassment, such efforts are harmful; but with tact on the part of the OOD, and an appreciation by the sonar operator of the real nature of the problem, such efforts are worthwhile.

3. Instructions which emphasize the importance of the task to be undertaken, and the constant or intermittent presence of a supervisory figure, both help to raise performance above control levels (2,3,18,19,21; Davies and Tune, 1969). The relieving OOD should spend no less than 10 minutes in Sonar Control prior to relieving the watch. He should see and listen to the prevailing acoustic conditions, and inform the relieving sonar operator(s) who should also be present exactly what the nature of operations will be during

the next watch. The nature of the bottom, water depth, and actual likelihood of encountering a submarine should be discussed. He should establish realistic goals for the sonar operators -- the goal is not to detect a submarine, that almost never happens; but rather to detect any ship that comes within 8,000 yards, or some other realistic figure. If the operator acquires an active contact, by knowing both the transmitter source level and the returning signal sound level he can determine propagation loss. With this information and if he then acquires passive contact he can compute target signal strength and see how it compares with tabulated values. He can make up his own table of observed values, and then attempt making passive detection range predictions for various types of ships. There are endless variations; observed bathythermograph traces can be compared to oceanographic atlases, and to message forecasts. Ray path plotting can be performed. Recordings of interesting signals can be obtained, with the ship maneuvering to assist. The results of this type of interest and coordination are sure to be better than that obtained when the operator's only task is to "detect a submarine." Similar interest should be taken in the Electronic Warfare area. The OOD, JOOD, and CIC Watch Officer should frequently and randomly visit these operators when circumstances allow. The benefits are two-fold: operator performance is enhanced, and supervisor knowledge of the task is improved.

4. The final recommendation is addressed to the operator himself. In passive search, there is no question of the great advantage gained by wearing comfortable high fidelity headphones. If not available on board, several should be obtained commercially. Good quality stereophonic headphones can be easily modified for this application. Submarine sonar operators, who make a career of passive search, would not consider standing a watch without this aid. In active search, a common practice for destroyermen is to remove the headphones in favor of the wall speaker. This is unfortunate, because without the close audio coupling that the headphones afford, faint echoes which would otherwise be detected can not be heard. Operationally this is easy to verify--simply compare the signals heard over the speaker and then through the headphones for some weak surface contact; it should be possible to determine (from radar) the range that echoes are no longer heard through each of these devices. The difference in range will be a measure of the performance improvement gained by using the headphones.

It is desirable to leave the wall speaker on, since other personnel present in the space might detect a signal missed by the assigned operator (6). The vigilance decrement with time for individuals exposed to noise and echoes from the speaker is not great (9), and would be even further decreased or vanish when the individuals shifted tasks. The audio threshold shift and ability to discriminate doppler due to this continual exposure is also negligible (20). If a very experienced "visitor" happens to be in the space and can overhear the speaker, very significant performance gains might be achieved (24).

As regards searching, the systematic beam-to-beam search which has been the practice for years (Sonar Technician, 1969) gives systematic area coverage as the ship maneuvers. With the ship stopped or on a constant course, it might be preferable to search from baffle to baffle. As with any search, intelligence which can help narrow the limits of the search should be sought out and used, and search sectors adjusted accordingly. Other operating parameters such as range scale, mode, and pulse length should be varied doctrinally and in a way compatible with the ship's objective and tactical realities. The only way to achieve this is to have open and almost continuous dialogue with all members of the "search team" -- the OOD, CIC personnel, and other sonar personnel.

H. ADDITIONAL REFERENCES

The effect of the environment upon ASW, if not well understood, is certainly well appreciated by anyone with experience in this field. Marsh (1950) presents a theory of the anomalous propagation of acoustic waves in the ocean. Somervell (1958) discusses the principal environmental problems related to ASW. Urick (1967) is a basic textbook dealing with the principles of underwater sound. Watson and McGirr (1972) provide a list of further references which deal with sonar performance and prediction.

V. LOOKOUT

A. NIGHT VISION (Generally from Jayle, 1959)

1. Requirements

The carrier landing accident rate in the U.S. Navy is four times greater by night than it is by day (Brictson, 1969). The death rate from automobile accidents occuring at night in rural areas exceeds the day rate by about 2½ times, in the cities the night death rate is about four times that of the day rate (Jayle: Accident Prevention Department of the Casualty and Surety Company, USA). The lookout at night must do all that is expected of the daytime lookout, plus he must be able to see at night. This fundamental requirement for good vision at night seems so clear that it is frequently assumed to exist, when in fact the lookout's adaptation is so incomplete that he might more accurately be assumed blind. Admiral Cope in his definitive 574 page guide, Command at Sea (Cope and Bucknell, 1966), considers the subject only briefly: "During inclement weather, the Officer of the Deck must give attention to ... night vision adaptation ... of his lookouts," and in an Appendix he suggests how the OOD should treat his own eyes, "Do not relieve the watch until your eyes are properly adapted to the darkness. While on watch, subject your eyes to light as little as possible."

Historically, the period shortly following watch relief is the time when collisions at sea most often occur.

If suddenly at night the visual acuity of all bridge watchstanders were reduced significantly, how much greater the risk of collision would seem to be. The simultaneous relief of key bridge watchstanders by improperly night adapted individuals represents such a situation. Under traditional bridge manning, with three lookouts, and an OOD and JOOD, such simultaneous relief occurs if five individuals are relieved as a group. Under the current Shipboard Automation and Manpower Reduction Project (Chief of Naval Operations, August 1972b), one lookout and a single OOD are specified; and simultaneous relief occurs when only these two are relieved together. If neither relief is properly prepared to see at night, then the situation is perilous indeed. The significantly greater speeds and reduced manning of next generation surface craft such as the hydrofoil, the air cushion/surface effect vehicle, and the semisubmerged catamaran (cf. Truax, 1973; Clifford, 1973; Naval Institute, 1973), further intensifies the problem.

2. Variables and Components of Night Vision

Nichols and Powers (1964) list six major categories of variables and conditions affecting visual perception in outdoor settings. Although not exhaustive, no fewer than 28 factors are cited (Brown, 1973 contains a review of later literature). Of these factors we have some control over the following:

1. Observer variables -- visual adaptation level, acuity at adaptation level, attention, motivation, training.

2. Situational variables -- instructions, time permitted for judgements, degree of search required, criteria for correctness of response.

We will consider here only the physiological variables affecting night vision. These variables apply not just to the designated lookouts, but to anyone who must use his eyes in near darkness. The Commanding Officer, arising from his sea cabin to check a contact; the navigator, balancing the need for darkness to see a faint star, against brightness to see the horizon; and the casual crewman strolling along the darkened deck who trips and is lost overboard -- any of these individuals could perform better if they were properly night adapted first.

Night visual perception has been investigated variously as responses to different luminous sensations which include:

1. Light sense -- ability to perceive faint light, graphically represented by the typical dark adaptation curve, Figure 4.

2. Differential light sense -- ability to distinguish one definite luminous area from another by comparison.

3. Morphoscopic sense -- ability to recognize the form of an object.

4. Sense of depth.

5. Sense of movement.

Experience shows that responses in the above five instances are similar, and yield basically the same adaptation curves. For the OOD conning a ship at night, it is important to remember that there is a diminution of stereoscopic visual acuity, or depth perception, in night vision which runs

and is the reason that under low illumination we see objects in shades of black and white. Rod sensitivity is rapidly lost at high levels of illumination and only slowly gained under low levels of illumination. About 25 minutes is required to fully adapt to darkness following exposure to sunlight. In general, the decrease in visual threshold during the first seven or eight minutes is due to an increase in the sensitivity of the cones, and, to a small degree, to the dilation of the pupil which increases the light-gathering power of the eye. The additional increase in threshold, which occurs after eight minutes, is due to the function of the rods. That period of time is entirely appropriate for the gradual darkening of the evening, but it can put serious limits on vision in other circumstances.

As suggested by the discontinuity in the adaptation curve, a dramatic change in the nature of seeing occurs with large changes in illumination. Nichols and Powers (1964) assembled tables and curves which allow a Commander to predict for various times of twilight and conditions of moonlight the luminosity of the night sky. A lookout whose light sense was less than this would perceive simply a black sky. If the ocean had no luminosity other than light reflected from the sky, he would also perceive a black ocean and no horizon. With time, more complete adaptation would be achieved, and the night sky might be observed. Stars and lights however might be seen at any time.

4. Unique Role of Red

Red light is the lowest frequency in the visual spectrum, and the rods are relatively insensitive to energy at this frequency (Wald, 1969). As red light intensity is increased we are able to perceive the light first through action of the cones, and we recognize it as the color red. Much more intense red illumination would begin to stimulate the rods, but this occurs above the level where red lighting is already adequate for good cone vision. This phenomenon explains why red goggles or red lighting measures produce night adaptation. Since red light does not stimulate the rods, the rods begin to adapt as if they were in total darkness. After about 25 minutes of such measures, essentially full adaptation is achieved. Similar adaptation begins whenever rod stimulation ceases whether the action is due to simply closing the eyes, sleeping, or entering a dark room.

5. Glare and Dazzling

Some degree of adaptation will be lost whenever glare or higher frequency (above dark red) light is present and allowed to enter the eye and strike the rods (dazzling). Protection against dazzling can often be accomplished by eliminating the sources. Automobile style electric cigarette lighters can be installed which have the effect of removing flashes of light from matches and lighters; black-out curtains, black paint, and tape do much to remove sources of dazzling glare. Pilot house windows should be kept

scrupulously clean not only to eliminate as much as possible dazzling reflections, but to maintain maximum transparency. A slight film of oil, dirt, or salt spray may cause loss of 50 per cent of the light passing through a window (National Search and Rescue Manual, 1959). Lighted status boards, compasses, and gyro repeaters should emit no light other than red. This is often accomplished by installing filters or painting the bulbs red. Red nail polish is very effective on smaller "peanut" bulbs. The typical bridge radar repeater is poorly human engineered from the standpoint of the night adapted eye. To obtain information from this scope, the OOD is required to look directly into and focus on a source of (often) non-red light. This display provides information invaluable to the shiphandler; it is not appropriate to deny him this data, yet the cost of a look is the loss of night vision.

A solution to this problem is to make a few large red filters, and keep them near the repeater. The OOD can place one, two, or as many as is required over the scope to appropriately filter the display and yet allow adequate target recognition. A more sophisticated variable density filter is proposed by Tousey (1945):

> This filter, "permits a continuous change in CRT colour from yellow to red, as well as dimming to blackout without change in colour. It consists essentially of two polaroid disks having a wave retardation disk sandwiched between them. By rotating only the outer polaroid disk brightness could be varied without colour change...By rotating only the retardation disk, the two polaroid disks remain parallel, the scope becomes redder and dimmer. In an operation where night vision was needed the operator, for example, a pilot, would set the display to be red during search and approach, and would blackout the display when visual control was sought."

Protection against dazzling from projectile, tracer bullet, or missile, flashes could be accomplished by staring in another direction, or closing one or both eyes. Due to a reduced field of view under night vision, staring away from a flash by 60 degrees or more places the flash outside of the peripheral field and affords some protection from dazzling. The rods of each eye respond independently to dazzling, so if one eye is shadowed by the nose, or protected by blinking, eye patch, or hand, adaptation of the protected eye will be maintained. Experiments have consistently shown that better night vision is achieved with both eyes functioning together than with one closed or obscured, so although adapting only one eye for night duties while using the other for daytime vigil is possible, it will not give us our best results.

Prolonged dazzling can also cause serious long-term night vision difficulties. Four and one-half hours exposure to sunshine such as would be experienced by sunbathers or deck workers (the usual lookout) has been shown to produce a 50 per cent night vision deficiency later the same day following 30 minutes of dark adaptation (Jayle: Johnson and Dreher, 1946). Other experimenters observed that the noxious effect of prolonged dazzling may remain several weeks (Jayle: Peckham, 1947). By wearing ordinary dark or polarized glasses the deficiency can be reduced considerably (Jayle: Hect, and others, 1948). Dazzling from the sunlight during a previous daytime watch would lower the efficiency of that

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individual at his nighttime watch. The daytime wearing of dark glasses (the darker the better) to prevent long term dazzling by all those who have nighttime visual responsibilities will improve nighttime visual performance (Jayle: Peckham, 1952; Bule, 1956). In an extreme case, night vision improvement was reported under wartime conditions where night lookouts were kept in darkness at all times, and used only for night lookout duties (Jayle: Angius, 1946).

6. Ambient Illumination

Visual acuity in a red luminance field is poorer than for any other color lighting, and visual fatigue is the greatest. In realization of this fact, recent ship alterations have been approved instituting blue lighting measures in shipboard Combat Information Centers (CIC's). This is accomplished by simply fitting blue tubes of cellulose acetate over "daylight" fluorescent tubes. Blue lighting gives the greatest visual acuity of any color illumination for a given intensity, exceeding even white light in this regard. In CIC's which have adopted blue lighting, visibility has been improved and dials or instructions can be clearly seen where formerly spot lighting or flashlights were employed. In some cities, emergency vehicles have been equipped with more visible blue warning lights. Low levels of blue ambient illumination also give a slight advantage over darkness in that the radar visibility threshold is slightly improved.

Unfortunately, blue light is perceived by the rods of the eye, and complete night adaptation will not be possible in such an environment unless red goggles are worn. A frequent complaint of personnel in blue CIC's is: "We can not see blue chart lines," or "The light is too bright." The U.S. Hydrographic Office has for years been working to remove red, orange, and buff from charts because of their tendencies to disappear under red lighting. This has led to the substitution of magenta or purple for red and orange, and gray for buff (Bowditch, 1966); and these later colors are difficult to see under blue. A chart should always be tested for this difficulty prior to actual use, and re-colored as necessary. The complaint about brightness is due solely to dazzling, and the fact that when the individual emerges from CIC he has lost his night adaptation and can not see well in the dark. If he had duties which did not require good night adaptation, and he remained only in CIC, then the "too bright" complaint would vanish. In blue CIC's, even without goggles, the lower intensity of the blue lighting typically employed allows some preadaptation to occur. This adaptation is not more complete than would be obtained while observing white light of the same intensity however. Because the Commanding Officer and other supervisory personnel are so often required to move between CIC and the bridge during periods of darkness, and the continual donning and removing of proper goggles to protect night vision seems so onerous, serious consideration should be

given to keeping CIC red. Extra fixtures or red filtered spotlights can be installed where particular individuals require additional lighting.

7. Red Glasses and Goggles

Several styles of red glasses and goggles are presently available both in the Navy supply system and commercially. From the standpoint of night adaptation the best goggles would prevent any light except dark red from entering the eye. Non-dense red lenses which emit principally red, but all other colors as well; dark glasses other than red, or small lenses that allow light leakage around the sides, are not particularly effective but will allow partial adaptation to occur. The partially adapted eye requires less time to become fully adapted under darkened conditions, but if all else is equal the light sense threshold will be the same as if partial adaptation had not occurred. The aviator style goggles which seal around the forehead, cheekbones, and bridge of the nose are probably the most effective protection and can be worn comfortably for short periods. Condensation on the inside of the lens and the heavy feeling of this mask become annoying when worn continually. Because of the goggle's high efficiency, OOD's and lookouts should wear them for at least 25 minutes prior to relieving the watch at night. This procedure is easily adopted by having the messenger hand goggles to the appropriate individuals as he wakes them.

For continuous use, wrap-around red plastic eyeglasses are available. These are comfortable and allow functional vision under normal illumination. The CO, XO, Navigator, and others who might be assigned responsibilities on the bridge can wear these glasses routinely at meals, movies, or other activities where overall red lighting measures are not in effect. If the need then arises, rapid complete adaptation will be possible.

This practice is common aboard submarines where it is extremely critical to ensure that whenever a periscope is exposed, the eye at the other end is performing in an optimal way. In surface ships, lacking the incentive of stealth, and possessing a multiplicity of visual and electronic sensors, it appears that good individual night vision is of lesser importance. However it is less than optimal from a systems standpoint to accept inferior performance from a particular sensor because of redundancy. Further, future ships simply will not have this degree of duplicity.

8. Summary

To secure the maximum night efficiency several conditions are essential:

1. The most complete dark adaptation must be obtained as speedily as possible.

2. This degree of adaptation must be maintained.

3. The maximum capability of the dark adapted eye must be utilized.

4. Protection against the adverse effects of general physical fatigue, lack of sleep, fasting, and various types of intoxication (alcohol, tobacco) is essential.

An adequate degree of dark adaptation is made possible by two principal factors:

1. A preliminary darkening, lasting about 25 minutes, corresponding to the time required for the normal adaptation curve to become horizontal.

2. An absence or limitation of prolonged dazzling during the period preceeding darkening.

These principles will help to ensure that our lookouts and others charged with nighttime visual responsibilities have the prerequisite visual thresholds. There remains the problem of utilization. According to Jayle (1959):

"Visual thresholds and nocturnal vision are two terms which have nothing or very little in common, but are generally mistaken one for the other. In fact, a proper night vision requires a sufficient night-visual threshold in much the same way as walking requires non-paralyzed lower limbs. However, the analogy does not extend any further, and it seems rather surprising that the psycho-physiological exploration of night vision has been until now commonly mistaken for the investigation regarding elementary thresholds."

The next section deals with the question of utilization, and will answer the questions of how to best conduct visual search once proper adaptation has been achieved.

B. SEARCH TECHNIQUES

1. Existing Practices

An unexpected benefit of our space program was the attention focused on the human factor problems of visual search. Fischl (1960) described the typical scenario:

"The objects of search were basketball-size capsules and larger vehicles. Some of the dimensions of the search task were that the vehicles were primarily afloat at sea, would have to be searched through an illumination range covering night with no moon through night with full moon to the high level of bright sunlight. Additional limiting factors in the search task were cloud coverages and discriminability from wave whitecaps. The search angles

through which the object had to be viewed were both large (search from aircraft at approximately 10,000 feet) and small (search from surface craft)."

In order to increase the probability of detection through visual search, definitive research in the following areas was called for:

1. "Research workers should be trying to pin down and quantify the effects of various magnification aids. Are they of any use in visual search? Are they purely for identification, and not to be used for search? ...

2. "We should like to see further definitive work in the psychophysiology of the visual mechanism in search tasks. This should lead to alternative methods for visual search, each with statements of the probability of detection.

3. "Also on the personnel, as opposed to hardware, side of the ledger we believe that once search methods have been treated a little more fully, programs of visual training may yield great dividends in maximizing the probability of detection.

4. "Finally, a comprehensive study of individual differences may provide clues leading toward a program of selection. It is not unlikely that some people may perform consistently better than others in a visual search situation and the development of protocols for identifying these individuals would appear to be time well spent."

Even with requirements for such definitive research, the solution of practical problems of search today still seems to be more of an art than a science. Even so, many "how to" guides espousing optimal search procedures are available. The following rules for night search are given in the British Civil Defense Instruction Manual (Jayle, 1959):

1. "Aim off with your eyes at night. Look a little to one side of whatever you want to see. Find which direction suits you best; above, to side, or below; but never look directly at what you want to see.

2. "Do not stare fixedly -- if you do, the image may fade and then disappear. Shift your eyes and the image will reappear.

3. "Do not 'scan' fast; move your eyes to a series of widely spaced positions, looking for a few seconds in each direction and pay attention to the things you are not looking at directly. If you think you see something, do not look at it, but look a little to one side of it.

4. "Stop scanning for 10 seconds every few minutes. If you scan continuously your eyes will partly black out.

5. "If you have to look at a lit area, protect the dark adaptation of one eye by keeping it shut. Learn to snap one eye shut instinctively whenever a bright light is turned on."

In a more explicative sense, the Watch Officer's Guide, a handbook intended for and used widely by U.S. Navy Officers (Noel, 1960) provides the following:

"Since, to see at night, you are using areas of the retina which you use only slightly most of the time, you must learn a special technique for distinguishing objects. At night, objects which can be seen "out of the corner of your eye" often disappear when looked at directly. Therefore, the trick is to be sure not to stare or strain the eyes in any single direction.

"A slow, roving gaze which systematically covers all quadrants of the sky or field of vision by a simple geometrical pattern picks up dimly contrasted objects. When you pick up an object this way, you naturally think of fixing your eyes upon it for a good look -- and right there, you may find it disappears. You can make it reappear by using "off center" vision."

For the most part, these doctrines have grown out of conclusions drawn from laboratory work, and are to some degree unrealistic. There is a real danger in general or basic research of so simplifying the problem to permit it to be handled more easily that it is not a problem any more. There has been very little applied research in vision.

The British procedure calling for a scanning technique of repeated fixations at widely spaced positions for a few seconds duration is in sharp contrast to Noel's technique of

a slow, roving gaze in a simple geometrical pattern. Laboratory experiments support either procedure, depending on the instructions given to the observers, nature of the target, constrast, and numerous other variables. The recurrent instruction to avoid staring directly at a dim target under night vision is based on the clinical fact that a central blind spot exists under night vision which for some individuals is as little as 1/2 degree, and others as much as five degrees (Jayle: Tibi, 1951; and others). Night <u>visual acuity</u> is clearest at four to six degrees from the center of vision. Night <u>light sensitivity</u> is greatest fifteen to twenty degrees from the center of vision (as references, the full moon's diameter is about 1/2 degree; and the back of a man's fist, held at arm's length, subtends about six degrees). This is in sharp contrast to our day-time visual acuity which is sharpest directly at the center of vision, and falls off rapidly at slight offsets. During the day, at ten degrees, our relative visual acuity is only twenty per cent of what we perceive in center vision (Thomas, 1969). Our daytime blind spot typically subtends five degrees, and is located fifteen to twenty degrees from center vision. The daytime blind spot is rarely noticed because of the overlapping fields of the two eyes; and because the "hole" occurs in our peripheral field, away from the fixation region, in an area where sharp vision is not necessary.

In spite of the problems inherent in applying the results of basic research to the development of a satisfactory general theory of search, we can develop some useful procedural rules which might be helpful in many cases. First, we must distinguish between day and night searches. The ability to see at night is in many ways independent of an individual's daytime visual acuity.

2. Problems at Night

Night blindness with no apparent decrement in daytime visual acuity exists at various times in many individuals from both psychological and pathological causes. Psychological night blindness has been observed in various neuroses, psychoses, and hysteria (Jayle, 1959). These factors which might exclude an individual from a ship's Reliability Program (Bureau of Medicine and Surgery, 1965) could also much reduce the effectiveness of such an individual as a nighttime lookout. Principal pathological causes are serious diseases which would disqualify a person from sea duty until cured, dietary deficiencies (Vitamin A deficiency most likely single cause), and diabetes and glaucoma. These later two diseases are mentioned because it is entirely possible that individuals assigned to shipboard duty today have undetected or undiagnosed diabetes or glaucoma, and even where detected diabetes does not necessarily disqualify an individual from destroyer duty. Congenital night blindness of varying degree is also possible. Aging has a significant effect on all forms of night visual functions, usually beginning at 40 years of

age, and becoming more pronounced after 50 (Jayle, 1959). Under these circumstances, a simple shipboard test of a lookout's night vision would seem an appropriate preliminary to any visual search doctrine. It is assumed that the lookout's daytime vision is 20/20 or has been corrected to that previously.

Night myopia (nearsightedness) occurs during night adaptation, and is maintained while the eyes are dark adapted. This is of practical significance to farsighted individuals who may see better at night without their usual corrective glasses. Myopes would need stronger corrections at night than during the day. For the normal eye, a corrective lens of approximately -1.5 diopters would give improved night vision. Ronchi (1947: from Jayle, 1959) found that when night myopia was corrected, a 50 per cent improvement in the night vision threshold occurred for a small test area. For a person who wears glasses and is used to them, a second pair with this -1.5d. correction is recommended for night use. For the individual who does not normally wear glasses, a nighttime lens of -1.5d. would improve his visual threshold; but the discomfort, and fogging or dirtying of the lens which he would not be accustomed to or otherwise have to tolerate, would tend to reduce his overall performance as a lookout. This phenomenon does explain why for clear binocular vision an individual will use different daytime and nighttime diopter settings.

3. Unaided Search

In search without binoculars, Coates, Loeb, and Aluisi (1972) determined that the observing strategy of gazing straight ahead was superior to scanning when the task involved detecting readily observed colored lights in the peripheral field. This technique might be useful when looking for a submarine flare from a known bearing at a fairly close range such as the yellow "surfacing signal"; but the more usual task requires searching for barely distinguishable lights or contacts on or near the horizon. Where the bearing is unknown, and the search area is wide (the air and sea to starboard for example), a scanning technique is required. The following major results were obtained from studies conducted by Brody, Corbin, and Volkman (1960) and Lovie (1966):

1. Systematic search generally reduced detection times for low contrast targets.

2. Free search was more efficient for high visibility targets.

3. The search time varies directly with the area over which the subject must search.

A recommended procedure for searching the horizon for low contrast targets or barely perceptible lights would involve some form of systematic search. Further, if we could reduce the lookout's search area, we could expect his efficiency to be increased by a proportional amount.

4. Search Specificity

A study undertaken by Martin Marietta Corporation (Fowler and Jones, 1972) found an almost linear relationship

between a searcher's field of view and both the probability of detection and time to detection. A relative increase in the observer's effective field of view is achieved by decreasing the area over which he must search. Much current shipboard doctrine has been developed utilizing this principle--sonar "search arcs," lookout "sectors of responsibility," and ECM "threat bands," are all designed to concentrate attention in a particular area.

While dogmatic adherence to "doctrine" might be a useful training device, searchers should realize that there is nothing inherently optimum in searching a greater area than required. As an example, the "60 degree sonar search arc" can be extremely detrimental to performance, particularly with today's longer range sonars where the angular search rate is so agonizingly slow. If conditions are such that a lost sonar contact can be localized within a certain 30 degree sector, then sonar should search this more specific area. Theoretically this refinement has just doubled the probability of reacquiring contact.

Practically, a systematic search that uniformly covers the entire field of visual responsibility is impossible to achieve under shipboard conditions. This condition is created in the lab by the use of visual scanners or masking devices, and approximated in some aircraft installations by automatic scanning exposure devices. Numerous experiments have been conducted establishing that coverage in any unaided search is grossly non-uniform (White and Ford,

1960a). An interesting demonstration of this fact is contained in the sequence of photographs obtained from the eye-marker camera of Thomas (1969) where the eyes' fixation points are superimposed on the scene before the viewer. When an observer is looking for something, his eyes move in a discontinuous fashion, so that information is gathered in a succession of discrete fixations separated by very rapid eye movements. The normal length of time per fixation is on the order of a third to a quarter of a second. This gives us two parameters which we might examine--the overall pattern of eye movement, and the fixation rate.

As previously mentioned, we can modify the lookout's search pattern with favorable results simply by giving him a smaller search area, or instructing him to concentrate his search in some important or high probability area. Since a visual lookout can not search wide sectors of sea and air assignment as quickly or as completely as he can search smaller areas, consideration of the capabilities and limitations of the visual lookout should be made in the context of the total sensory environment in which he is to be employed. With effective air search radar it is inefficient to have the lookout gazing skyward to detect aircraft. Low flyer detection, surveillance of the ship's helicopter, or identification of a flight in response to a question from CIC, is entirely appropriate but this in another employment. Similarly, with operable sonar the initial detection of a submarine by the lookout sighting a periscope is so unlikely

that as a general rule the lookout's capabilities could be more effectively utilized in some other role. The circumstances of each ship will differ, but the important concept is that the more control exercised over where the lookout searches, the more effective that search will be.

5. Eye Scan

Given a well defined search area, there are several techniques of eye scan which an observer may attempt to use. Several typical laboratory experiments compare horizontal scan, vertical scan, and even diagonal scan results. Where the observer must find targets in fields which have both height and breadth, no technique seems superior to layered horizontal search (Lovie, 1966). In the shipboard environment, where the field is horizontally stratified with the highest probability area often along or just below the horizon, it would seem that a horizontal search would almost always be preferred. Scans could be made most frequently along this high probability "band." On particular radials or sectors where a greater intensity of search is desired, such as directly ahead of the vessel for small objects or contacts; or directly astern to detect overboard equipment, oil, or personnel; then vertical search might be appropriate. This degree of instruction may be impractical or superfluous in most shipboard situations. Based on Teichner's (1960) analysis of several visual search experiments, most observers are unable to perform a patterned search even if they want to. Even under laboratory conditions and when so instructed

by researchers, subjects did not consistently carry out a sequential search process. Constraints of the medium, and "human factors" are often cited as possible reasons for this phenomena. This "human factor" is simply an acknowledgement of the natural tendency of observers to make fixations on objects, borders, or shapes which have entered their perceptual field and stimulated a visual interest either through movement, contrast, or color. If a person is searching, this type of stimulation simply overrides a premeditated scanning pattern.

Seeing is done during fixations, and 85-90 per cent of the total search time is occupied by fixations (Boynton, 1960). Even Noel's recommended "slow, roving gaze," is made up of a series of fairly rapid individual fixations. The possibility of increasing search efficiency by decreasing fixation time exists. In reading it is not uncommon to achieve gains of several hundred per cent by reducing this fixation time. The normal fixation rate in reading is relatively slow because of the habit of vocalizing--of saying, forming, or thinking a word to ourself as we look at it. Vocalizing slows down our fixation rate, and relatively slow fixations become part of our normal way of seeing things. Another factor contributing to this type of search lethargy would be our continuous exposure to commercial advertising. Knoll (1960) observed:

"The 'Madison Avenue' type spends his working hours devising methods of visual (and other) conspicuousness--he does everything to make the single glance probability equal to unity. His design is to reveal, not to hide--to reduce search to an absolute minimum. Extensive exposure to such simple visual displays may (and this goes beyond what one would call an educated guess) result in eye movement patterns poorly adapted to difficult search tasks."

"Speed reading" courses are available which train the individual to increase his fixation rate without mechanical devices (Evenlyn Wood Reading Dynamics is one). Scan rate is determined by fixation rate, and eye movement between fixations. In one experiment involving low contrast target recognition, the maximum detection efficiency was achieved by observers fixating every 1/2 second. The optimal rate varies considerably with the situation and the task of search (Townsend and Fry, 1960). With automatic scanning devices, this time can be as low as 1/4 second. Operational data analyzed by Lemar (1960) found observers using a relatively slow 1 1/2 second fixation and seems to support the hypothesis that operationally we scan too slowly to achieve maximum efficiency. Oldfield (1960) determined that eye movement should be sufficient to keep overlap between successive fixations at a minimum, and fixation intervals should be equally spaced.

The practical procedure recommended in National Search and Rescue Manual (1959) addresses the fundamental problem of optimum scan rate, and lets fixation rate and eye movement rate occur as natural consequences. According to the Manual, for search, eyes should move and pause for each three or four degrees of lateral and/or vertical distance at

a rate which will cover about ten degrees per second. Objects will normally be sighted within fifty degrees of the fixation point. At night, when searching for flares or lights, do not pause so frequently.

Fixating and scanning do require visual reference points, not only for structured search, but also for completely free search. In the lab these references are often artificially introduced. Automatic scanners or marks on a screen through which the subject views the field are common devices. Outside of the lab, such references often take the form of shapes or visual irregularities which we do not view directly but are aware of only peripherally. Such references seem to be a fundamental and necessary component of prolonged search.

6. Uniform Field Difficulties

There is a physiological cost associated with prolonged search into a very blank or uniform field such as sky or fog. Cohn (1960) summarized the results of his research in this area:

"After prolonged exposure to a uniform field, many subjects reported an experience of "blanking-out." For instance, the subject may report simply having a feeling of light with no external reference. In other instances, the subject may report "not seeing anything." In the more extreme phase of the phenomenon, which usually occurred only after prolonged exposure of 10 to 20 minutes, there was a "complete absence of seeing." In the last instance, the subjects were not only completely unaware of vision as a sense modality but seemed to lack feed-back from their eye muscles. They often reported that they were uncertain as to whether or not their eyes were open and were not capable of voluntarily controlling their eye movement. Although, blinking and eye movements usually were sufficient to bring about a return of the visual field during most "blank-out" experiences, this was not true for the more extensive loss of vision.

After a 20 minute exposure to the field, a variety of after-effects were observed. The subjects reported extreme fatigue along with a feeling of great lightness of body. Their motor coordination was poor and they were unable to maintain balance. Their perception of time was disturbed. They often complained of dizziness and behaved in an extremely giddy, almost drunken manner. One subject even reported suffering from temporary states of depersonalization. These effects are similar to those observed under much longer periods of sensory deprivation."

Analysis of many such experiments showed considerable individual differences, with some lookouts far more susceptible to the interfering effects of the uniform field than others. Exposure times as short as 90 seconds interfered with the recognition ability of some individuals.

These more immediate effects are due to a visual phenomenon that Sells and Berry (1961) have termed "empty field myopia." Whiteside (1957) describes this condition: Irrespective of the brightness or darkness of the environment,

"in the presence of an empty visual field, subjects cannot relax accommodation completely. Rather, accommodation is in a constant state of fluctuation...An observer with normal eyesight, then, is unable to focus at infinity if there is no detail at infinity that is capable of being sharply focused. Under these conditions the farthest he can focus is a point about 1 to 2 miles away, and he becomes effectively myopic by this amount."

Whiteside further determined that it can take as much as 60 seconds for the accommodation mechanism to completely relax and return to infinite focus once some specific object is sighted. National Search and Rescue Manual (1959) suggests periodically focusing the eyes on some specific object in the "no contrast" field such as whitecaps or debris. If this is done frequently, "only a second will be

required to break inward focus, and when the eyes are returned to scanning they will focus properly." The necessary conditions for empty field myopia rarely occur aboard ship, but in such cases the lookout would be unaware that he is focused short of the surface being searched and may miss targets.

Generally, relatively brief exposures to a uniform field are less detrimental from all standpoints than prolonged exposures, and attempts should be made to minimize the duration whenever possible. If continuous search is required, Cohn (1960) recommends some device which would permit periodic differentiation of the field. In the shipboard lookouts case, there would seem to be sufficient near-field distractions (lifelines, masts, superstructure, parts of the body including clothing and equipment, adjacent personnel) to give adequate differentiation. Another possibility would be to train the observer to blink frequently and look away from the field whenever possible. This later recommendation is the basis of the British Civil Defense Instruction to "stop scanning for 10 seconds every few minutes. If you scan continuously your eyes will partly black out." This habit of relaxed blinking should actually be practiced at all times as a technique which may prevent the onset of visual fatigue (McFarland, Holway, and Hurvich, 1942).

In a practical sense, it is unlikely that uniform field vertigo will occur in the shipboard environment. The great differences between individuals in susceptibility to

a partial degradation after as little as 90 seconds though makes it important to be aware of the effect; and instructions to lookouts, particularly in fog or during air operations, should include suitable precautions.

7. Binoculars

Binoculars have a rather limited but special place in visual search. Koopman (1946) considered the question of binocular assisted search and concluded that for most conditions of search, particularly whenever visibility is less than about ten miles, binoculars are not as effective as the naked eye. Operations Development Force (1951) analyzed data collected in searching with standard Navy 7x50 binoculars, and found that against low contrast targets the use of binoculars resulted in a reduction of search rate, even though greater ranges of detection were sometimes observed. Search rate reduction would occur to even greater degree with the variable power (13X, 21X, 25X, or 32X eyepieces available) ship's telescope, or 20 power mounted ship's binoculars. Smith (1960) modeled the binocular search problem with parameters which included target range, size, and visibility and achieved good agreement with the existing data. In the terms of Smith's model, the use of binoculars is seen to offer no advantage under any condition of visibility in considering search area per glimpse. In terms of scanned length (range from observer), binoculars are advantageous only when the meteorological visibility exceeds 20 miles. Only in terms of maximum range of sighting does the use of binoculars

appear to offer any advantage. Analyzing the results achieved with binoculars in one particular search, Smith concluded:

> "...under all but the highest visibilities, the use of binoculars is disadvantageous...When it is recalled that no account has been taken in this study of such factors as the increased effects of vibration and observer fatigue associated with binocular usage, this conclusion is further strengthened. However, because of the increased maximum detection range possible, binoculars can still be a valuable aid in identifying suspicious targets detected by the unaided eye or other means. Furthermore, when a large amount of search effort is available, tending to saturate the nearer ranges of possible target positions, it may be profitable to assign one or two observers to binocular search at ranges in excess of the unaided-eye capability. In practical operations, however, the likelihood of such a wealth of search effort is remote."

The man overboard procedure where the ship has completed a Williamson Turn (a standard procedure for reversing course) and is returning along her previous track, with the crew manning the rail in search, is one instance where a wealth of search effort is available and binoculars might be utilized to increase overall search effectiveness.

Where binocular search is appropriate, several recent studies by Sternberg and Banks (1970) and Banks and others (1971) show us how to achieve the greatest effectiveness. The studies themselves are of interest because they demonstrate rather clearly how analysis can lead a researcher in a sometimes unexpected direction, and that recognition of certain human factor principles can be the first step in realizing a significant improvement in system performance. In microcosm, that is what this paper is about.

The initial task in these studies had been to determine the effectiveness of a certain Army night vision device, and also how effectiveness could be improved. Early in the research, it was observed that operators were not performing effectively. The failure to detect more targets could not be explained by operator inability to see and discriminate targets in the field, nor to fatigue and lowered vigilance during prolonged use. It was also found that the problem could not be eliminated simply by more practice in using the devices. The major cause seemed to be that "the operators did not search the field thoroughly nor at an adequate rate." Although operators reported that they were systematically searching the entire area, large sections of the area were not searched for long periods because of backtracking and irregular search patterns. As a consequence, a large proportion of the targets missed were never even in the searcher's field of view.

To improve search effectiveness, techniques which would produce a systematic and comprehensive coverage of the search area on a regular basis were developed. Several alternative procedures were examined:

1. Continuous movement (at a variable rate) of the device, stopping only to examine some object of interest.

2. Discontinuous movement with the device moved in discrete steps and the image display examined for some (variable) period of time before the device was again moved.

Two variations of this second technique were introduced differing in the size of the step. Operationally, this variation in step size produced either an overlap or a

non-overlap of the adjacent segments of the terrain which were viewed through the device on successive steps.

Under analysis, either systematic method gave basically the same results. When compared to the results of search using the original more natural procedures, detection gains of 35 to 80 per cent were achieved. With a systematic search, operator performance on a 75 degree area was just about equal to that of an operator using original procedures on a 35 degree area. In this experiment a single operator using systematic search could cover a wide area as effectively as two men using natural search each covering half the area. Personnel should receive the following instructions pertaining to binocular search:

1. Use a regular search pattern which will produce a systematic and comprehensive coverage of the search area on a regular basis.

2. Use a variable scanning rate, with the rate of scan adjusted to the difficulty of the area being examined.

3. At night, binoculars should be held straight forward and the eyes turned off-center toward the perimeter of the field. This will always seem unnatural at first, but it is the only way to use night vision effectively.

Additionally, training should include care and cleaning of the binoculars, night and day focusing for each eye, and interpupillary distance adjustments (Signalman, 1968).

8. Search Summation

It should be clear by now that optimal visual search techniques cannot be specified as such in any general statement. Efficient, systematic eye scan alone is not the key. Boynton (1960) analyzed the eye movements of both

experienced photointerpreters and novices in the same search situation, and found they did not exhibit significant differences in eye movements. Fixations can occur directly on target, and that target might not actually be seen. This suggests that the most important kind of information that is needed for an observer to achieve optimal search is not a book of rules about "How to Search," but rather a solid background of information about target characteristics and the specific environment which is to be searched. This philosophy is consistent with our knowledge of other complex sensors. To properly employ Electronic Warfare equipment we must be thoroughly briefed on the nature of the target. To operate sonar most effectively we need to have up-to-date environmental information. The human sensor is no less sophisticated or complex. In addition, pre-task instructions are an important source of motivation in vigilance tasks, and this factor alone can have a significant positive effect (Lucaccini, Freedy, and Lyman, 1968).

There are, however, a few fundamental "ground rules" which seem to apply in many cases (Adapted from Morris, 1960):

1. Obtain a thorough briefing on what is to be searched for, where to search, for how long, and the importance attached to finding the object (or the penalty for not finding it).

2. Scan as fast as possible; use brief, rapid fixations which cover the greatest area in the shortest time.

3. Do not use binoculars for detection of targets expected to be at great or unknown range, or if time is limited. The advantage of magnification does not compensate for field size reduction.

4. Use binoculars for identification of targets once located, or in systematic search if use is specified.

C. ENVIRONMENT

1. Rain, Wind, and Cold

This Section is included to perpetuate the now wide-spread practice of keeping lookouts protected from cold and rain. It would be an unfortunate and incorrect interpretation of material presented elsewhere in this paper to conclude that the lookout will be more "vigilant" if he is kept cold; or that he will see better if he is outside in a heavy rain rather than in the pilot house peering through a slightly obscured window. An ingenious series of experiments was carried out aboard the H.M.S. Kent and reported by Poulton (1965). Actual shipboard watchstanders were observed under various conditions of rain, cold, and wind. It was concluded that in watchkeeping on the open sea:

> 1. "Performance is likely to be impaired in rain.
> 2. "Performance is likely to become impaired towards the end of the half-hour watch in the cold unless the lookout is wearing adequate cold-weather clothing."

Poulton recommended that where it is necessary for lookouts to maintain constant vigilance at sea:

> 1. "They should be protected from rain.
> 2. "In cold atmospheres they should be so clothed that their body temperature does not fall during the watch."

The degree of coldness depends upon the combination of temperature, wind velocity, and relative humidity, but any significant decrease in the body core temperature would be signaled by uncontrollable shivering. Under some conditions cold weather can cause injury and disability. Lookouts may occasionally be exposed to the hazards of frostbite.

2. Frostbite

Frostbite is superficial freezing of the skin following exposure to extreme cold generally at or below equivalent temperatures of 20°F. (See Table 2.) It is common on the face, hands, and feet. Its onset is signaled

Equivalent Temp. (°F.)		AIR TEMPERATURE (°F.)															
		50	45	40	35	30	25	20	15	10	5	0	-5	-10	-15	-20	-25
WIND VELOCITY IN KNOTS	0	50	45	40	35	30	25	20	15	10	5	0	-5	-10	-15	-20	-25
	5	45	38	34	29	24	19	14	9	3	-2	-8	-11	-19	-23	-28	-32
	10	38	31	26	20	14	8	3	-2	-10	-18	-25	-30	-37	-43	-48	-53
	15	33	27	20	12	5	0	-8	-15	-20	-28	-35	-40	-48	-58		
	20	28	22	15	7	2	-7	-15	-21	-27	-35	-40	-47	-58			
	25	26	19	12	3	-3	-10	-18	-25	-32	-37	-45			LESS THAN -60°F		
	30	25	17	10	1	-8	-14	-23	-28	-35	-43	-48					
	35	20	15	8	-1	-10	-15	-25	-30	-38	-45	-50					
		CHILL CONDITION II					CHILL CONDITION III			CHILL CONDITION IV			CHILL CONDITION V				

Table 2. Chill Factor Data. Equivalent temperatures for various air temperatures and constant (not gust) dry wind velocities (Bureau of Naval Personnel, 1973).

by a sudden blanching of the skin which may be subjectively noted as a momentary tingling sensation. The best treatment, according to Neil and Tyler (1973) is:

"prevention by wearing proper clothing and avoiding continued exposure. When the need exists for prolonged exposure, the "buddy system" of two men watching each other for the telltale, yellow-white spots will minimize tissue damage by early detection. In severe cold, if your face, hands or bare skin stop hurting, investigate. You probably have frostbite. When felt, frostbitten skin may be cold, frosty and stiff.

"The best treatment for freezing injuries is quick thawing in a water bath of 104° - 108°F. Superficial frostbite is rarely seen where such treatment is readily available. In the field or aboard ships, it should be immediately treated whenever encountered by placing a warm hand over the spot until it hurts again. Frostbite of the fingers can be treated by placing them inside your clothes and next to the skin. Under the armpits is an excellent place to warm the hands."

Frostbite, if promptly treated is not serious and will not result in any permanent damage to the tissue. If, on the other hand, frostbite is not treated and measures are not taken to prevent further prolonged exposure to the cold, dry gangrene with loss of frozen tissue can result.

At sea, warmer water often keeps air temperatures above the point where frostbite might usually be expected to occur. However, as shown in Table 2, when the air is dry, wind velocity is a significant factor in determining where the danger of frostbite first exists (Chill Condition II). With a fairly typical relative wind of 15 knots, frostbite can occur with dry air temperatures as warm as 40°F. Even with air temperatures as warm as 50°F, routine destroyer operations can produce relative winds in excess of the 35 knots required to produce frostbite.

VI. OFFICER OF THE DECK

A. AUTHORITY

The authority exercised by the Officer of the Deck in the execution of his duties is a function of policy established by the Commanding Officer. Often the OOD's performance is based more on his perception of this policy than it is on the broader shipwide objectives which the Commanding Officer actually seeks to satisfy. What the Commanding Officer must ensure is that in major policy decision areas, responsibility and authority are delegated in the way which will most directly contribute to overall readiness. This matter requires continual attention and adjustment, since optimal relationships are never static. In a study of organizational effectiveness, Valenzi, and others (1972) concluded: "Perhaps the most important point to note...is that 'successful' organizations changed in some way when the environment changed, while 'unsuccessful' organizations did not."

Shipboard duties are structured around battle readiness requirements, and the shipboard organization must be capable of acting in compliance with existing Rules of Engagement. These Rules in turn are subject to constant modification and refinement. Since no set of rules will cover all conceivable circumstances, the basic operating philosophy of the Commanding Officer must be clearly understood by each watchstander and related to his own duties in a completely non-ambiguous

manner. Goldhamer (1950) discussed the relationship between policy and performance:

"Another example of a major policy decision, the effects of which are probably quite diffuse and cannot be allocated to a particular point in an operation or campaign, bears on the lines of authority that policy establishes. Thus, for example, in American bombers command authority is vested in the pilot; this is not the case in Soviet planes. Is there an advantage in the latter procedure? From the systems analysis standpoint such questions become crucial only if such policy alternatives could 'sufficiently' alter performance level (either in a single strike or campaign). There are, of course, an endless number of things that could conceivably make a difference. What is required is a judgement, sensitized by contact with operating personnel and by general professional knowledge, on what possibilities one should not ignore."

Equivalent questions aboard ship focus on weapons release authority in a quick-reaction situation, optimal station for the Commanding Officer in various actions, and authority and responsibility of the CIC Evaluator relative to the OOD. In these cases at least, "sensitized judgements" are prerequisites to acceptable performance.

B. STRESS

"Stress" may be defined as a specification of the demands that requirements of a particular task place on the individual (Fitts and Posner, 1967).

"When stress is defined by the demands a task makes, it is immediately apparent that people do their best under intermediate conditions of stress. Remove all input--all environmental variation, all demands--and the individual at best becomes bored, loses alertness, and perhaps goes to sleep. At worst, he exhibits some of the hallucinations and cognitive deficit sometimes reported in experiments specifically designed to study sensory deprivation. People also do poorly at the other extreme of stress. Increase the task load to the point where it is impossible for the individual to keep up with the demands placed upon him...and performance again deteriorates. Man's best performance and the conditions of work that he reports as most challenging, stimulating, and conducive to maximum effort, are found in between such extremes."

Figure 5 is a classical representation of how man's performance might vary with stress in a particular situation.

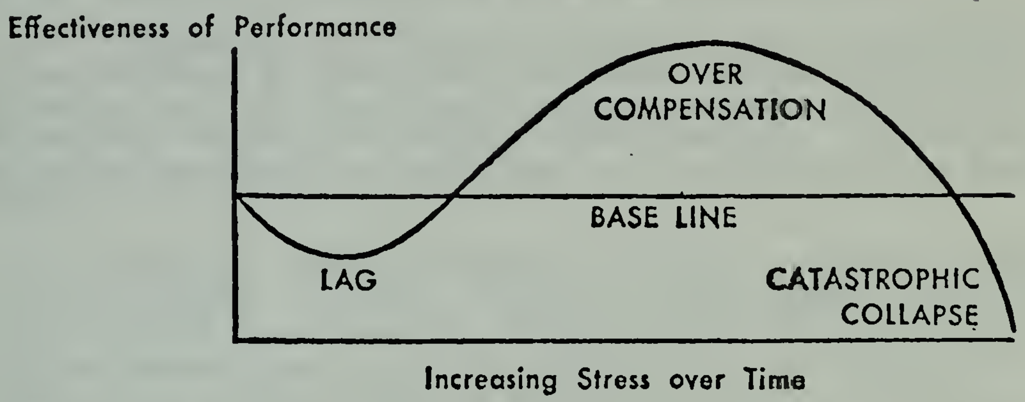

Figure 5. Typical Performance/Stress Relationship (Hare, 1962)

Task demands contributing to stress do not have to be real. The anticipation of unpleasant events can have a marked effect on an individual's behavior, in fact anticipatory stress may sometimes be more disruptive to behavior than the event itself (Waldeisen, Curran, and Wherry, 1967). According to Hudson (1952), "the real issue in threat research is the manner in which the individual perceives his environment."

Two questions immediately arise from the relationship between performance and stress: first, how does an individual adapt to input overload, or task stress; second, how may the condition of stress that he prefers or finds most conducive to successful effort be imposed? According to Miller (1964a),

man has four basic mechanisms for adapting to input overload:

1. Work faster and faster and let errors increase; in other words, make less carefully considered decisions and respond without considering all the information.

2. Disregard or filter out part of the information. Wherever there is some basis for establishing priorities, filtering out the less important information permits the individual to do a relatively effective job. He handles important messages or decisions and simply puts the remainder aside.

3. Queing. Input messages and other work are simply allowed to wait in line. In most complex tasks, this waiting line is short-term memory. Man's ability to cope effectively with patterned input, and to organize his own patterned output, is in large measure dependent on his ability to accumulate a small amount of information before beginning to respond to it.

4. Collapse. The individual may simply stop work for a time. This may seem highly nonadaptive, however in some situations it is desirable. This is the traditional "All Stop" order to the engines when the OOD becomes confused about what the engines are doing and which way the ship wants to go.

Most experimental evidence suggests that the optimal level of irrelevant stimulation increases as the level of task difficulty (relevant information) decreases (Yerkes-Dodson Law: Broadbent, 1965). This means that for an easy task the optimal level of irrelevant stimulation will be much higher than it is for a difficult task. Thus, repetitive tasks can often be best performed while listening to the radio or to an outside conversation; while serious work involving much concentration is hampered by outside stimulation. Fitts and Posner (1967) state:

"These data all suggest that relevant and irrelevant stress are compensatory to some degree. That is, what is important is the total level of stimulation, both relevant and irrelevant. We have optimal performance when the total

stimulation is at some intermediate level...Moreover, the effects of stress are not static, but change as the task goes on."

The Commanding Officer has some control over the quantity and rate of stress-inducing stimulation in the OOD's environment. With experience the OOD builds up an ability at doing two tasks at the same time (Kalsbeek, 1964); but this ability is limited, and when overload occurs he will adapt to the conditions with increasing inefficiency. The level of stress can be reduced by reducing the OOD's responsibilities, perhaps by temporarily assigning additional personnel to the watch. There also exists the possibility of obtaining optimum performance by varying the level of stress perceived by the OOD, even though the level of environmental stimulation remains constant. A nod of approval or expression of trust can greatly relieve the anxiety or stress felt by a harassed OOD, and the result should be reflected in his performance. Conversely, performance on a low-stress mid-watch might be greatly enhanced if the environment could be made somewhat more stressful. The practice of holding unscheduled man overboard or other shiphandling exercises, intra-ship maneuvering board or signal drills, quizzing OOD's unexpectedly on the status of the ECM or Sonar search or on acoustic or engineering conditions, or inquiring about the recognition features of reported contacts, are all ways of increasing the OOD's perceived stress. There are many others, and when practiced with tact and sensitivity the results might be favorable.

C. WATCHSTANDER HEALTH AND PHYSICAL WELL-BEING

1. Illness, Coffee, Alcohol, Medication, and Seasickness

Studies of the behavioral effects of infectious diseases have shown (Alluisi, 1969) that the average performance efficiency of a crew can drop between 25 and 33 per cent during a period of serious illness. This study also pointed out that:

> "of greater importance, however, is the extent of the differences in the performance decrements exhibited by different persons--persons who appear to be equally and fully ill with the disease as judged clinically and measured biomedically. One subject might show essentially no drop in performance, whereas another subject's performance might drop entirely to zero--the subject's having become essentially non-responsive to the environment."

It is this great variation in individuals that the OOD must be constantly sensitive to.

Coffee, a stimulant, tends to improve vigilance performance and reduce the decrement over time. Depressant drugs have been shown to impair vigilance performance in numerous experiments--error rates have been increased and detection rates have been reduced in both auditory and visual tasks (Davies and Tune, 1969). Alcohol and Meclizine Hydrochloride (an anti-motion medication available aboard ship) act as depressants and affect some individuals more than others. Some people are sooner incapacitated by seasickness or inoculations.

The shipboard environment places great stress on individuals, and the OOD must be aware of the general physical condition of each of his watchstanders. Individual adjustments

may sometimes be required as a result of these conditions in order to achieve the greatest overall efficiency.

2. Snacks and Smoking

An important factor contributing to the watch-stander's sense of well-being is authorization to eat snacks or smoke. In at least one study, light snacks have been shown to improve the vigilance performance of lookouts. We have already mentioned the stimulating effects of coffee. A study by Tarriere and Hartemann (1964) investigated the effects of tobacco smoke on a visual vigilance task. This work was extended by Davies and Tune (1969) who found that:

> "When smokers were allowed to smoke during the performance of a 150-minute visual vigilance task their performance was significantly better than when smoking was not permitted. The principal difference was in the amount of decrement shown. When the performance of smokers was compared with that of a group of non-smokers, the latter showed a bigger deterioration in performance with time at work. Of the 3 groups tested, smokers who were permitted to smoke produced the best performance, followed by non-smokers, and smokers unable to smoke performed worst."

Johnston (1966) reported one study which showed that inhaling smoke from two standard cigarettes decreased the light sensitivity of the dark adapted eye slightly, and the effect persisted for 15 to 30 minutes. Evidence was also presented that smoking affects peripheral acuity, and that peripheral acuity affects search performance. It appears though that the adverse clincial effects of smoking are insignificant when compared to the overall positive mental or psychological effects derived in the operational environment.

VII. ENGINEERING WATCH

Initially, this section on the Engineering Watch was to have been fairly lengthy, and would have consisted mainly of material on illumination, and noise/heat/vibration. After researching these topics, it was found we could deal with some of these aspects rather quickly. More importantly, the emphasis was shifted to the significant human factor of isolation, and concludes with a discussion of how the principle of knowledge of results can be applied to improve engineering performance.

A. ILLUMINATION

Difficulties in measuring the psychophysiological cost of work under varying levels of illumination and other factors have led to disagreements as to applicable minimum standards for different jobs. In a practical sense it does not seem possible to achieve too great an ambient level of illumination in any engineering space; in the absence of any definitive study to the contrary and from a maintenance, operations, and cleanliness standpoint the greater the level of illumination in these spaces the better.

B. NOISE/HEAT/VIBRATION

1. Cost and Nature of Hearing Damage

"Other than as a damaging agent to the ear and as a masker of auditory information, noise will not harm the organism or interfere with mental or motor performance."

(Kryter, 1970). In the Navy, standards for equipment noise are based on average damage thresholds and include, "HEL Standard S-1-63, AFR 160-3, BuShips Specification S-1-10, BUMEDINST 6260.6B, MIL-STD-740, or MIL-A-8806, as applicable." (COMOPTEVFORINST 3930.1F, 1970). Where these standards are exceeded, a hearing protective device is required. Although performance may not be decremented by noise in this limited sense, the long term effects from exposure to damaging noise are costly for the individual and his service. In 1970, the Veterans Administration paid out $52 million in direct compensation to hearing loss victims who had no other disability. An unknown additional amount was paid to veterans with hearing losses along with one or more other disabilities. In that same year, hearing aids, batteries and hearing aid repairs cost the VA another $1.4 million (Navy Times, 1974). Hearing impairment and deafness can be congenital or can be caused by diseases, infections, combat wounds, other traumatic injuries, or by malfunctions of the ear not noise-induced. The biggest cause of hearing loss among military personnel is, however, unprotected exposure to excessively loud noises. Fortunately, it is also the hearing loss against which the individual can best protect himself. Regrettably, too many do not. According to Revell (1974), a hearing disabled Marine Corps veteran:

> "Probably one big reason for this lack of self-protection is that men rarely see the consequences of it until it is too late. I never saw dramatic, sudden deafness in others, caused by some failure to protect their ears at some specific time and place. It just doesn't happen that

way. The fiddler gets paid later. An Air Force colonel can't hear at age 45; he wore no ear protectors while a machine gun instructor in his early 20's. An Army veteran began wearing a hearing aid this year at age 33; he didn't protect his hearing as an Army tank crewman in the late fifties. The examples go on, by the literal thousands, but the people who haven't yet been damaged don't see these disabled former non- (now true) believers in hearing protection."

2. Shipboard Noise Hazards and Thumb Rules

Shipboard compliance with provisions of the Navy's noise abatement and control program is typically manifested by the presence of protective ear muffs on the helicopter deck during flight operations, and an occasional sign reading "Noise Hazardous Area" in some engineering space. Most are familiar in principle with standard noise level tables such as the following:

Sound	Decibels (dB)
Whisper	20
Conversation	60
5-Ton truck	87-101
Light Helicopter	102-111
CVA Flight deck	130
.45 caliber pistol (30 feet away)	140
M16 rifle (firer's position)	154-158

Nearly all aircraft used by U.S. forces generate noise above 85 dB, the ears-at-risk point. All individual and crew-served weapons in the U.S. inventory generate noise at or above 120 dB, the threshold of physical pain (Navy Times, 1974)

Virtually all noise-induced hearing damage is preventable with the protective devices now available. In practice, good protectors reduce noise reaching the ear by about 15 dB in the lower (not very harmful) frequencies,

and by about 35 dB in the higher (extremely harmful) frequencies. Since not all hazardous noise areas are marked, and since noise-level meters which measure and define such areas do not account for differences between individuals, the Air Force has developed a helpful rule of thumb (Navy Times, 1974):

For steady-level noise, "If talking with another person requires the speaker to raise his voice to be understood by a person one foot away, or to shout at three feet, the noise is hazardous.

"The other kind of noise hazard, impulse noise, doesn't lend itself to seat-of-the-pants measurement. However, as a practical rule of thumb defense against the most common military impulse noise, gunfire, consider it all hazardous, even plinking .22 caliber rifles and pistols."

3. <u>Hearing Protective Devices</u>

Navy Times also discussed hearing protective devices in use by the armed forces:

1. <u>Reusable ear plugs</u>: The two basic service-issued ear plugs are the single-flange and triple-flange models. They come in up to five sizes to fit different size ear canals, are made of soft, preformed vinyl and are intended for repeated use. They should be fitted to the individual ear to be effective. Ear canal sizes vary between individuals and even occasionally between a person's two ears. Properly fitted plugs are snug but not uncomfortable.

2. <u>Disposable ear plugs</u>: Several versions are in the supply system. One is made of wax-impregnated cotton. They fit everyone and are intended for one-time use. Another "disposable" plug is made by National Research Corporation, which uses a foamed polymeric material with extraordinary sound-absorbing properties. Trade-named "E-A-R Plug," it is a .6 by .7 inch compressible cylinder that can be rolled between thumb and forefinger to about .2 inch. Inserted into the ear canal, it expands in a few seconds to a snug fit in any size ear. They can be washed and reused.

3. <u>Ear muffs</u>: Muffs are very similar to stereo headphones, but with much tighter seals against the head. They attenuate slightly more sound energy than most plugs. In steady-level noise above 120 dB, wearing both ear plugs and muffs provides better protection than either device worn

alone. Combined muffs and plugs do not provide better protection against impulse-type noise, though. "Audio muffs" are similar with a built in phone speaker for flight deck use.

4. Universal-fit ear plugs: This device fits all ears because it is held in place with a headband. The only real advantage is this universal fit.

5. Emergency protectors: If you get caught in hazardous noise without plugs or muffs, stick a finger in each ear. If you need your fingers for something else, try wet cotton, as dry cotton is worthless. Cotton impregnated with wax also is good. Any item that seals the external canal can be helpful in an emergency.

Protective devices do not prevent hearing conversational sounds. The devices reduce the conversational (low) frequencies only a little, while reducing the dangerous, high-frequency sounds a lot. In a noise environment, you frequently can hear those sounds you need to hear better if you're wearing muffs or plugs. Exposure to noise has a cumulative damaging effect on hearing, and the virile self-image and fearless attitude manifested by shunning ear plugs today will doom a person to forever fumbling with a hearing aid in his senior years. Hospital Audiology Departments or any practicing otolaryngologist could provide names of former military personnel residing in the local area who might be willing to discuss their hearing-loss experiences with the crew. In addition to the mechanical and electronic adjustments, the psychological acceptance of a hearing aid as a "life-time crutch" is often difficult; discussions with such an individual might be enlightening to some crew members and could do much to prevent this unnecessary and often self-inflicted injury.

Hearing impairment is often not obvious to the afflicted individual, and others will detect a problem before he perceives it himself. Due to various operational circumstances, regular hearing examinations and audiograms are often not performed, even on sonarmen where the requirement so clearly exists. Early hearing loss detection can be a powerful incentive to begin a conscientious personal hearing-protection program. Although permanent damage is irrevocable, further damage can often be prevented. Navy Times (1974) provided some useful indicators of hearing loss:

4. Shipboard Tests for Hearing Loss

a. Consonant discrimination: "The sound energy of human speech is carried mainly in the low-frequency vowel sounds. Comprehension, however, is carried in the low-energy, high frequency sounds. Particularly troublesome for the person with the high-frequency loss are the b, c, d, g, p, s, t, v, and z sounds, the m and n sounds and combined letter sounds, such as ch and sh. An inability to discriminate readily between these consonant sounds can be a first indication of a hearing problem. Try this list by having someone read randomly while you don't watch the reader's face: bill, chill, dill, drill, fill, frill, gill, grill, hill, Jill, kill, mill, nil, pill."

b. Soundless aids: Some studies indicate that more than 50 per cent of communication between persons comes through nonverbal aids: body language, movements of the mouth, lips, tongue, and throat, filling in the unheard blanks based on the general context of the conversation, anticipating what is coming next, and attitudes of the head, hands, arms, and legs. A marginally-hearing person may fail to understand speech when some or all of the nonverbal aids are missing.

c. Built-in background: Most high-frequency loss sufferers hear constant strange noises, a "ringing" in the ears. Even persons with normal hearing sometimes have the problem, brought on by colds, or trauma. Hearing speech through this ringing can be difficult in an otherwise quiet environment.

d. Feminine voices: Soft, relatively high-frequency feminine voices are difficult for high-frequency-loss victims.

e. Articulation: "Another manifestation of hearing loss is indistinctness of the victim's articulation. Spoken sounds are repetitions of sounds heard. A hard-of-hearing person doesn't hear some of the hard consonants, forgets the sounds or remembers and believes he's pronouncing them, and leaves them out of his speech. He may pronounce pit, for example, leaving off most or all of the hard, plosive p. It may come out bit or even it."

f. Body language: "Finally, the partially-deaf person's own body language can reveal his problem. He may regularly turn his ear, the best one if there's a difference, toward the person he's trying to understand. He may cup his ear with a hand in the universal I-can't-hear-you signal. He may watch a speaker's mouth, instead of maintaining the more common eye contact."

Any of these signals should be interpreted as a requirement for competent medical examination.

5. Effects of Noise, Temperature, and Vibration on Performance

In studies where a relationship between noise and performance is claimed (For example: Lawton, 1972), this can be taken as due to psychological factors related to stimulus and response contingencies as associated with the noise by the individual. It is generally the nature of the individual, and not the nature of the noise, which determines performance in the presence of noise. Bregman and Pearson (1972) find:

"Man has demonstrated a unique potential to perform tasks in the presence of noise, and frequently shows an amazing ability to adapt to, or apparently ignore, forms of noise in his home and work environments. Research from our laboratory...has shown wide individual differences in attitudes toward noise and in sensitivity to common noise sources."

An experiment in an operational environment looked at the combined effects of noise, temperature, and vibration (Loeb and Jeantheau, 1958). Four conditions were studied:

a. <u>Control condition</u>: moderate noise and heat, no vibration

b. <u>Noise and Vibration</u>: noise and vibration considerable, temperature moderate

c. <u>Heat condition</u>: heat rather intense, noise moderate, no vibration

d. <u>Heat, Noise, and Vibration</u>: noise, vibration, and heat levels rather high.

The Summary of Results concluded,

"Noise and vibration...appreciably increased the median response times of the subjects. Further decrement occurred when heat was combined with noise and vibration, but the effect was relatively transitory. Heat alone had no apparent effect. Changes occurring as a function of elapsed time were not apparent."

C. ISOLATION AND KNOWLEDGE OF RESULTS

1. <u>Small Group Psychology</u>

Through an unfortunate combination of circumstances including physical remoteness, unavailability of information, aptitude, and probably even disinterest, the typical engineering watchstander performs the routine duties of his watch in relative isolation. Whether by choice or chance, he

probably has less knowledge about the immediate operations of the ship he mans than anyone else on board, lookouts and messcooks included. He may at times share the companionship of a small group of fellow watchstanders; but this is of little comfort today and will be of less help in the future. Consider the following from Shipmate (1973):

> "The Navy's first gas turbine destroyer was launched on 10 November at Pascagoula, Miss.....USS SPRUANCE (DD-963) is the first of 30 destroyers of this class, six of which are now under construction, the first major combatant type to use gas turbines for propulsion. The high degree of automation of this power plant is a significant factor in the low number of men (250) planned for assignment to Spruance class DD's."

When we have at last reduced the engineering watch to that single irreducible man, cost-benefit and manpower-utilization studies will unquestionably show that we have achieved new and better efficiencies in operating our ships. The feeling of isolation experienced by that remaining man, similar to feelings shared by small groups of watchstanders now, will not be quantified. The "errors" he makes, the deterioration in performance that is very likely to occur, these things will simply become problems for local commands to solve. Fortunately, the problem is neither new nor unsolvable.

The study of small groups seems to encounter almost insurmountable methodological obstacles when attempted in the laboratory. Given the proliferation of variables determined to influence individual and group behavior and the often conflicting results generated by studies examining only one or a few aspects of group behavior, there are serious limitations of the laboratory in providing complete

information about long-duration, complex interactions from brief investigations of highly restricted subject populations. Studying small group performance under conditions of isolation becomes even more fragile. Hopefully, future research will involve the systematic study of natural groups over time (Helmreich, Bakeman, and Scherwitz, 1973). Motivation for much of the older literature on sensory deprivation and social isolation were reports about American POWs in Korea who were reputedly subjected to similar conditions (Myers, 1961; Army Leadership Human Research, 1962; Myers, and others, 1962, 1966; Smith, Myers, and Murphy, 1963; Myers, Smith, and Murphy, 1971). Similar studies with perhaps greater applied value address the problems of isolation and confinement aboard submarines and Sealab (cf., Levine, 1958,a,b; Radloff and Helmreich, 1968). The latest generation of available literature deals with the human factors in jet and long-duration spaceflight (Sells and Berry, 1961; Townes, 1972). Much of this information is applicable to the destroyer environment.

Townes discusses the problems of groups in isolation:

> Data cited "suggests that <u>time</u> may be a highly relevant variable in the perception of superordinate goals (i.e., goals that are compelling for all group members but that require interdependent activity for attainment) and that a strong tendency exists for progressive social withdrawal and individuation in conditions of long-term group isolation and confinement. Since systematic studies of isolated groups have been limited to relatively short durations, it is not known how far this process goes...However the possibility must be considered that a mutual withdrawal and encapsulation process may proceed over time to such a point that superordinate goals and interdependencies are

de-emphasized to the extent that they no longer maintain group viability. In the light of current knowledge regarding the importance of feedback in adaptative systems or of reinforcement in behavior modification, it can be safely presumed that adaptative interpersonal relations will depend on interpersonal communication, whether verbal or otherwise. This process of social withdrawal and individual encapsulation seems very likely to impair appropriate interpersonal communication.

"It has been observed both anecdotally and in laboratory studies that in socially isolated groups the degree to which men seek and obtain stimulation in the form of interpersonal information may in itself create problems in that men become "overexposed" to each other (Byrd, 1930; Smith, S., 1969; Altman and Haythorn, 1965). This overexposure may result fron an accelerated rate of information exchange relative to the rate at which group members are able to develop shared values, behavioral expectations, and belief systems...An accelerated rate of information exchange may produce interpersonal stress which in turn produces or at least is accompanied by social withdrawal and encapsulation, thereby heightening the degree of stimulus reduction.

"One might expect that a program of stimulus enrichment could be easily designed to offset these effects of stimulus reduction...any stimulus-enrichment program for a long-term period would have to provide stimuli that were both novel and significant to the individual." Self-actualization is a term which involves adaptation to what is seen as a meaningful and important life. Stimulus must be provided so that the individual "fits his niche, so to speak, bringing his interests, skills, and personality predispositions into play in ways that are intrinsically satisfying to him.

"It seems unlikely that such individuals (groups in isolation) would readily find opportunities for self-actualization simply as passengers on a long-duration mission during most of which time they have little or nothing of an actively useful nature to accomplish. So-called "Mickey Mouse" tasks would not provide the realistic challenge such individuals may require to maintain their active orientation to reality...The goal here is to provide a realistic, challenging task that will keep crew members meaningfully involved in interdependent activities directed toward a superordinate goal. The mission itself constitutes a superordinate goal...but does not require a high degree of interdependent activity en route.

"Educational and recreational opportunities would, of course, facilitate long-term viability...News from (home) will be important to the crew, not only because of their interest in what is going on but as a relief from the

monotony of the mission. Communications will permit inclusions of (those at home) in the psychological life-space of the crew. Crew members will not be entirely dependent for all social contacts upon other crew members: they should receive considerable social support from...their families...

"It seems that the long-term viability of the human group under such conditions will be intimately related to ...the degree to which a challenging task and meaningful variety of stimuli can be provided, and the effectiveness with which procedures can be designed to maintain interdependent activity on the part of crew members directed toward superordinate goals.

"It is recommended that a systems-analysis approach be applied to study and redefine the human-factors requirements...All the elements of the long-duration mission, including its (predeployment) and (post-deployment leave and upkeep) portions, should be considered together as a totally integrated and mutually reinforcing system."

2. Education, Physical Fitness, Morale

In many important ways, these observations of small group needs help to reinforce traditional practices. The Navy's Program for Afloat College Education (PACE: NavPers 15229) provides educational opportunities. Chief of Naval Operations (1973) provides for general military training which includes clear and challenging health/fitness instructions for shipboard personnel. Physical fitness programs have become a corporate trend; Exxon and Phillips Petroleum have well publicized stateside programs, Japanese employers have similar requirements. Where performance can be measured by earnings, it is not difficult to justify expenditures for health/fitness maintenance. In laboratory tests, exercise programs have contributed towards physical fitness with attendent improvement in psychomotor reaction times, and decrease in degree of anxiety, depression, and hostility (cf., Lambert and Parrish, 1972; Phelan and Parodi, 1971).

Efforts to provide challenging tasks and stimulus-enrichment on board ship are never-ending. The Commanding Officer's "only collateral duty" is frequently that of "Morale Officer." Cruise-books, ship's newspapers, the library, smokers, and movies (Cope and Bucknell, 1966) satisfy many of our needs. Mail, Family-grams, and when authorized even radio-telephone relays help to keep us in contact with our families. Occasionally an innovation attracts wide attention, as was the case with Reduced Manning (Destroyer Development Group, 1973).

3. Reduced Manning

A recent newspaper article quotes: "Navy Still Studying 5-Man Watch Team--Purpose of the test is to develop 'watch team esprit' and ultimately reduce shipmanning." (Navy Times, 10 October 1973). The premise is that performance gains achieved by manning the bridge with highly cohesive groups will offset the losses due to reduced resources. In reality, "watch team esprit" will exist pretty much in the form that it does today, as long as the goals, aspirations, and relationships that motivate the teams remain unchanged (Kurke, 1962). Although some Commanding Officers have instituted successful team-building initiatives (Destroyer Development Group, 1973) it is primarily the addition of the automatic-bell loggers, steering devices, fog-signal timers, and special communications gear plus economic necessity which allows the reductions in manpower.

However, installation and acceptance of this automatic equipment without regard for the attendant human factors problems will inevitably lead to operational inefficiencies or failures. The necessity of revising both the human and non-human elements of the system was pointed out by Naval Ship Research and Development (1969):

> "Before the ultimate goal of minimum manning levels are possible or unmanned machinery spaces can be realized in the Naval Service, an intermediate phase must transpire. Several factors will highlight this phase, one being general acceptance and a buildup of confidence in the automation concept at all levels of the Naval establishment. The second factor will be a gradual improvement in the performance, quality, reliability, and arrangement of the control systems themselves. The third factor deals with personnel capability, which must be upgraded through revised concepts in training together with revised methods in personnel utilization."

4. <u>Counseling</u>

A factor that went unidentified in the preceding discussion of groups in isolation yet was tacitly acknowledged as absolutely vital to mission viability was "knowledge of results." In the shipboard environment, knowledge of results is provided through many channels; morning quarters, casual personal encounters, announcements in the Plan-Of-The-Day, recognition at inspections, presentation of awards, and surreptitiously in "shipping-over" discussions and during career counseling (Meshi, and others 1972; Holoter, and others, 1973). These last two references are a description of the Navy career counseling process, and a report of findings based on a large sample of the Navy enlisted population. These findings stressed the need for

"practical techniques for improving organizational effectiveness, and for creating a more favorable social envelope within which the individual Navyman can live and work..." Chief of Naval Operations (1972a) in a move to increase counseling effectiveness increased the number of full-time career counseling billets to all sea commands having more than 200 enlisted members.

In addition to such full time counselors, every leadership billet in the navy carries with it the inherent requirement that an incumbent be an effective counselor. Modern techniques encourage active involvement between the counselor and the counseled, and give the counselor a perhaps unique opportunity to bolster the individual's personal feelings of worth and contribution. This is a broader interpretation of "knowledge of results" or "feedback" than is usually allowed, however it is important not to view counseling as simply a technique to improve retention. Counseling viewed in the context of the total Command, and conducted in a way compatible with overall Command objectives, can be expected to have a significant positive effect on performance. An important "lesson learned" from the campus disturbances which began at Berkeley in late 1966, and expanded to the protest of 50 thousand demonstrators at the Pentagon on 21 October 1967, was how relatively ineffective our then existing student development and counseling techniques really were. The dissenting young who joined in these protests yesterday are

in the Navy today; the bulk of the enlisted men assigned to our modern guided missile destroyers are 19-21 years of age (Pinney, 1967). The procedures that were found useful in restoring order to the campuses then are applicable to us now. Layton, Sandeen, and Baker (1971) summarize these lessons:

"In recognition of the need to help students develop, college counseling centers are gradually giving up their passive and reactive roles isolated from the mainstream of student life and are changing into student growth and development centers with the focus on the educational and developmental tasks in addition to the traditional remedial functions (Levy, 1969; Foulds and Guinan, 1969; Lipsman, 1969). Carey (1969) stated that student protests indicate that counseling has been ineffective in that the individual student's needs have not been met satisfactorily. He said that the counselor should be the listener of students and learn of their attitudes, values, and needs before the students take indirect ways through demonstrations and violence to indicate what their needs are. Such listening will necessitate the counselor moving out of his office to where the action is and feeding the information gained into proper administrative channels so that change can occur. Lawton (1970) and Calia (1966) ahve also emphasized the need to move out."

5. Techniques and Results of Feedback

Perhaps one of the most direct and effective sources of feedback to the crew in general, and to the engineering watchstander in particular, is the Ship's Announcing System (1MC). When desired, it can be directed to this group exclusively. The Engineering Officer of the Watch has available an equivalent system for these spaces, but more often it is not amplified to be heard by all watchstanders. Indiscriminate use of the 1MC in these spaces can be annoying, and under some circumstances dangerous; but when used with discretion and a great deal more regularity than is common

today, there is little doubt that the 1MC can be an important source of reinforcement for this group. A "tremendous boost in morale" was noted in a widely published Destroyer Squadron Commander's letter (Wolfe and Mulholland, 1960) where there was "a continuing effort by ship's officers to keep the crew "cut in" on what was going on and why--including blow-by-blow accounts of ASW actions via the public address system." Feedback does not have to be of an informative or even truly factual nature to be effective.

Mackworth (1950), for example, in one of the studies in his classic series, called each subject by telephone midway during the watch period to ask him to "do even better for the rest of the test." Performance, which had shown a substantial decrement before the telephone message, recovered to a level higher than initial levels. Similar effects have been observed in countless laboratory studies examining feedback. Direct knowledge-of-results is one important type of feedback, and there are variations (Fitts and Posner, 1967). The following typical experiments may provide some feeling for the subject:

1. McCormack (1959) in measuring response times to a light stimulus with and without knowledge of results, found "response time increased significantly throughout the duration of the task, this increase being more pronounced under the no-knowledge than under the knowledge condition."

2. Baker (1960a) in a study of radar operators found that providing knowledge of results by voice over head-phones improved performance.

3. Jensen, Tilton, and Anderson (1961), observing the crew at a radar station in the United States, conducted experiments that indicated "knowledge of results and discussions contribute to improvements in performance by

helping to develop understanding of the environment and common modes of response among members of a group."

4. Baker, C. H. (1961) in a vigilance task maintained performance at a high level by giving knowledge of results concerning performance of a peripheral vigilance task which was undertaken concurrently.

5. Weidenfeller, Baker, and Ware (1962) in an experiment involving monitoring of a simple visual display where knowledge of results (KR), "false" knowledge of results (FKR), and an irrelevant stimulus (IS) were provided to different groups found no significant difference in performance by the IS group over a control group, but found both the KR and FKR groups significantly higher by the same amounts.

6. Sipowicz, Ware, and Baker (1962) investigated groups monitoring an interrupted light source under isolated conditions with KR, monetary reward, or both, and concluded that all experimental groups were significantly better than the control group. The combination of reward and KR produced the highest level of performance, however "the effectiveness of reward is highly dependent upon the manner in which it is used."

7. Hardesty, Trumbo, and Bevan (1963), in a modified Mackworth Clock Test, observed the effects of observer-presented KR, machine-presented KR, and the physical presence or absence of an observer with the subject. "On the initial test day, groups with no knowledge of results and machine-presented knowledge of results showed the typical decrement function throughout the session. In contrast, subjects receiving verbal knowledge of results from the experimenter showed less decrement and a significantly higher over-all performance. The superiority of the groups receiving the verbal report persisted on the two subsequent test days despite the fact that all extrinsic knowledge of results was withdrawn on these tests. Observer-presented knowledge of results facilitated performance regardless of the physical presence or absence of the observer in the test cubicle."

8. Ware and Baker (1964) attempted to determine which method of presenting KR (verbal or nonverbal) seemed to have the greatest effect on performance for auditory and visual vigilance tasks. In terms of detection performance, they found "verbal KR was superior to nonverbal, auditory superior to visual, and KR for misses superior to KR for detections. When KR was presented verbally, response category made no difference in performance level, but knowledge of missed signals, when presented nonverbally, was significantly higher than knowledge of detected signals."

9. Mackworth (1964) found that the performance decrement over time in vigilance, threshold, and high-speed perceptual motor tasks can be prevented in both active and passive tasks by knowledge of results.

10. Antonelli and Karas (1967) investigated the effects of both true and false knowledge of results in experiments involving the monitoring of a display panel. The results demonstrated that "groups receiving KR do not differ significantly in performance from groups receiving FKR. The best results were obtained at the 100% feedback level." A performance drop of about 25% occurred when only 50% feedback was provided.

The moral for destroyer operations is plain. Provide feedback in all its many guises, as frequently as possible, with all the ingenuity at your command. Optimum performance will not be achieved otherwise.

VIII. COMMANDING OFFICER

A. FATIGUE AND SLEEP LOSS

Under laboratory conditions, a differentiation can perhaps be made between the physiological and psychological aspects of fatigue in terms of characteristic muscle and brain electrical 'fingerprints' (Lloyd, Voor, and Thieman, 1968). Aboard ship we are more interested in how fatigue and sleep loss effects overall performance. The question of what per cent of a certain performance decrement is physiological and what per cent is psychological is largely moot. Just how difficult it is in the field to make such distinction is evident in the findings of Wilkinson (1964) who studied the effects of up to 60 hours of sleep deprivation on different types of work and concluded:

"The effects of sleep deprivation upon performance vary widely with the nature of the work being carried out. In the present study impairment was almost complete towards the end of 20 min repetitive serial responding and 30 min inspection work (vigilance). On the other hand, tactical decision making of a complex, but absorbing and realistic nature was completely unaffected by the same degree of stress even towards the end of one hour's continuous work. What are the features of a task which determine whether its performance will be impaired by loss of sleep or not? Two are suggested. A task will be vulnerable to sleep deprivation (1) as it is complex, and (2) as it is lacking in interest, incentive and reward. Of the two factors, that of incentive may be the more influential, such that a highly complex task may be little affected by sleep deprivation if it is complex in an interesting or rewarding way."

Sleep is not a continuous steady state, and with the advent of modern techniques for sleep monitoring and data processing there has been a tremendous amount of new information made available on the cyclic nature of sleep stages

and the mental, biochemical, and physiological activity that occurs during sleep. One result of the increased study in this area has been to correct the old belief that extensive sleep deprivation would inevitably result in marked behavioral changes, often including hallucinations and paranoid delusions. Johnson (1967) reported effects observed in total sleep loss experiments:

"Although one subject was kept awake for 264 hours, no marked psychological changes occurred. Other studies reported only minor changes after 200 and 125 hours of sleep loss. Whether sleep loss will result in psychological changes appears to depend upon the age of the subject (the younger subject has more resistance), his psychological and physical health before the ordeal, and the expectations and support given by his environment.

"Sleep loss, however, does produce changes in performance, with the nature and extent of such changes depending upon several factors. After prolonged sleep deprivation, the primary impairment takes the form of lapses. The subject is unable to maintain efficient behavior and increasingly experiences short periods when performance falters or stops. In general, when he can control the display of stimuli and the rate at which he will respond, his performance suffers less. Speed may be impaired but accuracy will be maintained. However, in work-paced tasks where the subject cannot control the time of appearance or duration of the stimulus display and must respond quickly, lapses will cause an increase in errors of omission.

"Under acute sleep loss, sending orders (a subject-paced task) results in fewer errors than receiving and sending out orders (work-paced task). Tasks with strong incentive qualities and of brief duration suffer less than tasks which are long and repetitive in nature. Immediate knowledge of results helps to overcome the effects of sleep loss. It is also well established that performance during the sleep loss period follows a diurnal cycle: the best performance usually occurs in the evening and the poorest around dawn."

Performance degradation due to sleep loss is affected not only by individual differences and the nature of the task, but also by the nature and length of sleep obtained. Fairly wide publicity of early demonstrations that sleep can be

divided into cyclical stages (Dement and Kleitman, 1957) and popular interest in the apparent relationships between rapid eye movements (REM) and dream recall, has led to the rather widely held and largely erroneous belief that sleep interruptions, by themselves, somehow deny the body some of sleep's restorative or recuperative function. Since much of shipboard sleep is interrupted sleep, research conclusions from specific studies in this area are particularly germane. Johnson, and others (1970) analyzed data from subjects who had undergone total sleep deprivation for two consecutive nights, and were allowed to recover by either:

1. Uninterrupted recovery sleep for five nights.

2. Two nights of REM deprivation and then three nights of uninterrupted recovery sleep (this REM deprived group was allowed all non-rem sleep).

3. Two nights of slow-wave sleep deprivation and then three nights of uninterrupted sleep.

A fourth group was allowed approximately eight hours of uninterrupted sleep every night, with no initial sleep deprivation whatsoever.

Findings were summarized as follows:

"Performance on the Wilkinson addition test, auditory vigilance, X crossout test, Williams immediate word recall test, and the mental adding test (plus 7), deteriorated significantly during total sleep loss. Fewer signals were detected on the vigilance task, fewer additions were attempted, fewer words were scanned on the crossout test, and fewer words were recalled in the memory test. Accuracy in all tasks tended to decrease as sleep loss increased.

"All subjects improved after the first night of recovery sleep. There was no significant difference in the amount of recovery for the three kinds of recovery sleep."

This finding suggests that the oft heard counsel "Don't wake the Captain, he's been up all night," is without substance.

Such interruptions apparently have no significant effect on sleep recovery, however arousal from partially adequate sleep can lead to very poor performance as will be seen.

Morgan and Alluisi (1972) conducted research to determine "the length of time (hours, days, weeks) a unit can perform its primary mission effectively before it must be relieved, plus the length of time before it is operationally ready for commitment again." One of the principal results of this research has been increased awareness of the effects of temporal variables such as work-rest schedules, sleep-wakefulness cycles, circadian rhythms, continuous work, and sleep loss on work behavior or sustained performance. (Circadian rhythm is the typical diurnal cycle of biological processes manifested by changes in respiration rate, oxygen consumption, gastrointestinal activity, heart rate, body temperature, blood pressure and many other metabolic functions. Performance has a very similar variation as earlier demonstrated by Kleitman (1939), Hauty and Payne (1958), and Murray, Williams, and Lubin (1958): Bennet, Degan, and Spiegel, 1963). It was observed in the course of this research that regardless of the work-rest schedules adopted (i.e., 4-2 work-rest, 4-4 work-rest), that the worst performance always came at the end of the sleep-loss or continuous-work day. "In the case of each subject, the very worst performance was obtained <u>after</u> the sleep-loss period had ended; i.e., it occurred during the first duty period following the inadequate four or two hours sleep of the

subjects who had been awake for 44 or 40 hours, respectively. In the case of the...(subjects)...who had been given a 24 hour rest period, the best performance occurred during the first work period after the sleep-loss stress." The recommendation from this is: "If men have endured a stressful period of sleep loss then gone to sleep, one had better not awaken them for duty prior to their having obtained adequate sleep unless one is prepared to expect very low performance efficiency."

1. Effect on Memory

Sleep loss also appears to have a degrading effect on man's short term memory. Williams, Gieseking, and Lubin (1966) found significant impairment after one night of sleep loss in the ability to immediately recall word lists. A similar recognition test 24-hours after a one night sleep loss, however, showed no significant deficit. Since in the normal course of operations watchstanders and others will perform their duties under various conditions of fatigue and sleep deprivation, information processing and display systems should be designed to compensate for failures in man's short term memory. Even under the most favorable of circumstances we may seriously overestimate memory capability, or fail to allow for very significant differences between individuals. Small individually maintained "status boards," or hand held "cheat sheets" should not necessarily be discouraged or viewed with disdain. What should be most important is the individuals total performance, and if he seems to do better

with some innovative "help," then he should be praised.

According to Hind (1967):

"Operators should not be required to remember important information, because they have inherently a large long-term memory but poor speed and accuracy of recall of information. Therefore, aids for recall or factual display of important information should be provided as necessary, the information being released when no longer required."

2. Sleep Control Methods

Adequate sleep seems to be beneficial for many reasons. Nevertheless, sleep-inducing drugs should be used with great caution and reluctance because of side effects. This problem was studied by Townes (1972) who advised:

"A more promising and healthful approach, not only to the control and attainment of optimal sleep but also to the regulation of waking states of relaxation and alertness when needed, is through conditioning and learning techniques. These procedures should be directed toward control of physical, physiological, and mental states involving muscular relaxation and regulation of activity of the central and autonomic nervous systems. Where sleep cannot be regulated properly, the effects of sleep loss must be combatted by countermeasures...these would include exercise, frequent changes of tasks, frequent rest periods, (and provisions for arousal if circumstances require)."

3. Work-Rest Cycles

An advantage that the military reader often enjoys over the civilian researcher in the area of watch schedules and work-rest cycles is that the former frequently has first hand knowledge gained through years of watchstanding on his own under a multitude of conditions, and the later has only imperfect data collected from a limited number of subjects (who may not be representative) under very particular circumstances (which may not be applicable to the present case). Extrapolating from laboratory data which attempts to answer

questions such as: "How much sleep is needed?" and "What is the best watch schedule?" to the world of destroyer operations would be possible, but the constraints and "subject to" caveats which would be errected around such an answer would probably obscure the general principles which we are looking for.

In an analysis of work-rest schedules in continuous operations, Morgan and Alluisi (1972) have drawn from a great wealth of studies of sustained performance conducted over various conditions by numerous investigators with different backgrounds and approaches. Their conclusion from this study was:

> "Performance efficiency can be maintained at a high level with men working as much as 12 hours a day on a 4-4 schedule, if other conditions are arranged appropriately. Previous indications of increased efficiency's being obtained with eight hour work days relative to longer ten or twelve hour work days apply to the conditions in which off-duty time must be spent in ... "housekeeping" functions ...
>
> "For short periods of time, in emergencies, and when extra-curricular demands are reduced or ignored, there is no question concerning man's abilities to work 12 or 16 hours per day, and with a maintenance of high levels of performance efficiencies. As part of the job of planning for the efficient, satisfying, and honorable employment of man we will certainly have to consider work-rest scheduling, durations of work within day, week, month, and longer periods, and the extra-curricular "housekeeping" demands made on all of us."

This was consistent with the earlier findings of Alluisi and Coates (1969):

> 1. "Man can probably follow a 4-4 work-rest schedule for very long periods without detriment to his performance.
>
> 2. "For shorter periods of two or possibly four weeks, selected men can follow a more demanding 4-2 work-rest schedule with reasonable maintenance of performance efficiency.

3. "In following the more demanding schedule, man uses up his performance reserve and so is less able to meet the demands of emergency conditions such as those imposed by sleep loss.

4. "The diurnal rhythm which is evidenced in physiological measures may also be evidenced in performance depending on the information given to, and the motivation of, the subjects, and depending also on the total work load; even where motivation is sufficiently high, the cycling may be demonstrated when the operator is overloaded."

4. Watch Schedules

It was in consideration of work-rest cycle optimization that Stolgitis (1969) analyzed the traditional Navy watch system and a proposed alternative. The Traditional watch is utilized by virtually all units of the surface Navy, and consists of a four hour watch (followed by eight hours off, or 4/8), with the 1600-2000 split into two "dog-watches" of nearly equal length. The Proposed Alternative was the less common six hour watch system (followed by twelve hours off, or 6/12) adopted in the past by crew preference aboard USS TECUMSEH (SSBN-628), USS STONEWALL JACKSON (SSBN-634), USS DANIEL BOONE (SSBN-629), USS ULYSSES S. GRANT (SSBN-631), USS SKIPJACK (SSN-585), and selected watches aboard USS JOUETT (DLG-29), to name only a few.

The basic assumptions of the Stolgitis analysis, based on a large body of supportive evidence which was cited and generally consistent with present theories on fatigue and sleep were:

1. "The fatigue differential caused by the additional two hours between four hour and six hour watches is not significant.

2. "The performance decrement as pertains to vigilance does not disappear with less than three hours of sleep.

3. "A minimum of five hours sleep is required to enable the individual to maintain an acceptable level of consistent and reliable performance.

4. "The physical and psychological recovery from sleep loss is accomplished by the acquisition of a normal uninterrupted sleep period."

In conclusion, "An analysis of the 4/8 and 6/12 watch schedules has indicated the 6/12 system to be the better system for providing adequate sleep periods. It achieves this goal by establishing longer uninterrupted hours of sleep for the individual. With the 4/8 schedule, the longest non-watch period is 8 hours. Within this length of time, the sailor must allocate time for ship's work, meals, personal hygiene, social activities, etc. It is immediately clear that a normal 8 hour sleep is not possible with the above constraints. The 6/12 schedule by virtue of its 12 hour periods of non-watch provides a greater opportunity for the individual to accomplish his necessary duties and also allot time for sleep that is closer to the 8 hour norm than the 4/8 schedule. It is this characteristic of the 6/12 schedule that makes it preferential."

Not only was the 6/12 watch schedule viewed preferable from the standpoint of providing adequate sleep periods, but the inference was drawn from the crew preferences for the 6/12 schedule that in this case "what is preferred by the individual is "best" in that it will lead to higher levels of morale and performance, and these traits are certainly the best means to the achievement of the military mission." This is a subjective view; but 6/12 and perhaps other alternate watch schedules could be considered and perhaps attempted in an effort to improve human performance.

B. EQUIPMENT ALTERATIONS

Specific shipboard alterations or modifications are often considered which may have some human factor advantages. Whether approval or disapproval of such proposals is made at the local level, or a recommendation is passed to some higher

level, the safety of the men and equipment affected by the alteration is often of paramount concern. The following discussion of the safety ramifications issuing from various proposals to improve a submarine depth gauge installation has broad applicability in the destroyer environment (Madison, 1972):

"Submarine safety, like gunnery laws, is written largely in the blood of individuals who have gone before in an unsafe manner. Time has obscured many of these lessons, and the particular safety features of a design remain for years after, seemingly without reason, but to be fully appreciated when the casualty which introduced the precaution reappears. So it is that the human factors designer must be alert not to remove such designed in safety merely to make what he believes will be a better system, or one more suitably adapted to the human factor requirements. The choice between placing a certain depth gauge in an area of the most acute perception by the OOD, or of placing it more remotely in a difficult to see area, might be made in favor of the later area once it is pointed out that during a crash dive three people must jump through the 'favorable' area, and a gauge placed there would almost certainly cause serious personnel injury.

"In the same way, piping changes, rate instruments, differential pressure detectors, and new alarms installed with the most admirable intentions of improving the man-machine relationship to achieve better system depth control performance might have just the opposite effect. Adding depth gauge piping increases the probability of a flooding casualty, since you now have a greater surface area exposed to the full pressure of the outside sea. Adding new equipment reduces the room available in which to maintain the old equipment, increases the system maintenance requirements perhaps at the detriment of a more important system, and actually increases the likelihood that a failure will occur. Generally, the simpler a system the less likely it is to fail. New alarms require new training and familiarization by all personnel who work in the area where response to the alarm is required. A man from a ship on which the alarm is not yet installed might become confused and commit an unsafe act on a supposedly identical ship which does have the alarm.

"In the case of maintenance it is by no means enough to simply install a reliable depth gauge. What is required is a gauge that, working in concert with the human operators, achieves the most complete integration in the total system,

and contributes to a maximum extent to the mission goal while having a minimum import on the man. No human factors improvement can be considered so 'obvious' that it can be installed and forgotten. Safety in human factors design is the sum of many factors, some intangible and difficult to quantify."

Even if equipment was once installed embodying the very best in human factor design features, and that equipment has been satisfactorily used for years, it is not always true that the same man-machine relationships exist today. Alterations or improvements to outdated equipments are often possible and desirable. Assignment decisions relative to man-machine functions are always made at some point in time, and relative to a particular state of development of engineering science. Chapanis (1960) observed,

"not so very many years ago, a question about the allocation of computing functions to the human or to a machine would have been meaningless. Computers for performing this kind of function have only recently become possible. Similarly, although it is essentially meaningless now to ask whether a machine sensing device should be used to recognize targets, this question may not be meaningless twenty years from now."

In cases where a need for improvement or alteration appears to exist, the following checklist, presented in the form of a set of questions, may help to solidify thought on the subject (adapted from Van Cott and Kinkade, 1972):

1. <u>Human Engineering Checklist for Equipment Alterations</u>

1. Why is the alteration being sought?
   What mission will the system be expected to fulfill?
   More particularly, what is this modified system expected to do that the existing systems are not doing or are not doing well enough?

2. How is the system to fulfill its mission?
   What are the stages of mission execution?
   What functions must be accomplished by the system at each stage?

3. In what environments must the system function?
What particular hazards will obtain?
What stresses or demands are likely to be placed on the system?

4. Who will benefit by system operation?
Who will use the system?
What kinds and numbers of operator and/or maintenance personnel are available?

5. What are the major technological options?
What alternative configurations are feasible?
What particular resource or class of resource is most crucial to prospective system effectiveness?

6. What functions should be assigned to human operator and support personnel?
What conditions will impose peak task loads on the operator or operators?
What conditions (e.g., long periods of inactivity) will tend to degrade operator performance?
What pattern of decision/action will occur at crucial periods?

7. What information is required by operators (and/or support personnel) in order to fulfill their functions?
What is the probable pattern of channels and flow rate for this information?
In what form (i.e., voice, audible alarm, written format) will the information be most useful to the operator?

8. How many people are needed to man and support the system under normal and peak load conditions?
What special skills, capabilities or attributes are needed for effective operator performance?
What special training, if any, will be required?
Is such training feasible?
What resources will be required to implement the training?

9. How should the assigned functions be distributed among operator and support personnel?
How should the work stations be arranged?
What instrumentation is required at each work station?
How should this instrumentation be laid out?

10. What specific devices, tools, or controls are most appropriate to the pattern of task actions that will be imposed on operator and support personnel?
What kinds of aids, guides, indicators, locks, interlocks, cover plates, etc. would be useful to facilitate correct actions and prevent operator errors?

What means are available to allow quick recovery or to maintain the safety and integrity of the system in the event of operator error or failure?

11. What options are available for eliminating, combining, or simplifying any of the instrumentation?

12. What safeguards, if any, are required to insure adherence to the design plan and functional requirements of the system?
    What quality control procedures are required to insure the validity of human factors considerations in the final product?

13. What will be the effect, if any, on human performance, safety, or morale of any proposed changes in configuration or instrumentation?

14. By what means can test and evaluation be made as realistic as possible in terms of the ultimate operator and support personnel and in terms of the operational conditions?

15. What criteria of system and operator performance are logical in terms of the mission and functions assigned?
    What measurement procedures will yield data which are valid with respect to such criteria?
    What test instrumentation is required?

16. What form of test design will yield unequivocal answers to questions of the effectiveness, operability and maintainability of the system?
    What is the most economical way of implementing the test design required?

In the U.S. Navy these later needs are often met through the research and analysis efforts of the Operational Test and Evaluation Force (Carmody, 1972). COMOPTEVFORINST 3930.1F Volume II (13 November 1970) is a two inch thick document which contains numerous human factors references and checklists for use in systems evaluations. Examples of the type of material contained in this reference are:

1. Chapter 3, Human Factors (52 pages).
2. Annex D, Master Checklist for Human Engineering (2 pages).

3. Sonar/Radars/Fire Control Systems Checklist (18 pages).
4. Weapons Systems Checklist (6 pages).
5. Communications Checklist (10 pages).
6. Electronic Systems Checklist (6 pages).
7. Annex E, Human Engineering Questionnaire (2 pages), with Worksheet (8 pages).
8. Personnel and Training Master Questionnaire (2 pages), with Personnel Data Sheet (2 pages), and Personnel and Training Requirements Assessment Questionnaire (38 pages).

Numerous related Tables and Figures are also provided.

Easterby (1967) makes very clear the limitations of checklists such as this. Its limitations are that it is at best an analytical tool; not one for synthesizing a new development but rather for attacking something wrong. Given a set of objectives to be achieved within given constraints and with specified resources, a checklist is of little value. As a data-gathering tool, a checklist has its value, but it provides very little insightful activity for the formulation of solutions. The checklist provided here is a carefully organized series of questions to assure the best possible acquisition of data. The complementary purpose is to guide, systematize, and force the asking of pertinent questions.

2. <u>Human Engineering Measure of Effectiveness Criteria</u>

The human factors principles presented in this paper, coupled with the questions suggested by this Checklist, will provide the means to obtain the human factors goals which are most important to destroyer operations. The payoff in human engineering is determined by concrete operating dividends which manifest themselves in the performance of the final system. Some typical criteria, which can be used

as yardsticks for assessing the effectiveness of the human engineering effort, are described below (Adapted from Van Cott and Kinkade, 1972):

1. Improved Performance. The man with the "right assignment," the "right tasks," the "right equipment," and the "right environment" is likely to be an efficient equipment operator or maintenance technician.

2. Reduced Training Costs. A man needs less training to operate a device when both the device and the operational procedures are properly engineered for human use. If he fits the device and the device fits him, and if the task procedures are optimum, he reaches the required standard or proficiency with less expenditure of time, money, and effort.

3. Improved Manpower Utilization. Tasks and tools are optimally human engineered when they minimize the need for special skills or high aptitudes in the human operator. More of the manpower pool can then be trained to do the tasks, thereby improving manpower utilization. A measure of the human engineering contribution to system design is the percentage of the available manpower that can perform the required tasks. In the face of limited manpower resources, it is essential that our human resources be used with utmost effectiveness.

4. Fewer Losses From Accidents and Misuse. Poor equipment design causes many of the accidents commonly attributed to human error. Poorly designed equipment tends to be used incorrectly or not at all.

5. Increased Economy of Production and Maintenance. Simplification of design often results in devices that are not only easier to operate, but simpler to manufacture and maintain. The application of the principles of human engineering will frequently lead to more economical production and maintenance, in addition to increased operator effectiveness.

6. Improved User Acceptance. A good system designed for ease of operation and maintenance, as well as for the safety and protection of its personnel, inspires confidence and increases efficiency. While some frustrations are inevitable, one goal of human engineering is to ensure that frustrations caused by troublesome or hazardous equipment or procedures are reduced to a minimum.

Criteria such as "Performance," "Manpower Utilization," and "User Acceptance" may be adequate to justify certain modifications or alterations at a strictly local level, however as these same recommendations are passed to higher levels for review, or proposals are considered for fleet-wide applicability, more specific or quantitative measures of effectiveness are often sought. For example, in analysis of the Pilot Program for the CNO Shipboard Automation and Manpower Reduction Project; Destroyer Development Group (1973) considered not only subjective evaluations of Commanding Officers and Officers of the Deck, but also considered such specific criteria as:

1. How well does the steersman steer?
2. How quickly does the watch react to ship control orders?
3. How well does the OOD maintain station?
4. How well does the signalman perform?
5. How well does the lookout perform?
6. How well are tactical circuits employed?
7. How well is the bridge supported by the CIC?
8. How well does the bridge perform administrative functions?
9. How efficient is the interchange between the signal bridge, the CIC, and the bridge?
10. If applicable, who augmented the five-man bridge watch?
11. How long was the bridge watch augmented?
12. Why was the bridge watch augmented?

The question "How well does the steersman steer?" can be answered by collecting data on ship's base course and actual course at randomly selected times. Similarly, reaction to ship control orders could be measured by observing times of helm or engine order changes and times of response. Desired and actual range and bearing to the guide at randomly selected times could measure the OOD's station-keeping ability. A conclusion or recommendation based on this type of data, where some measurable change or improvement is obtained, is often more acceptable than the identical conclusion based on opinion or experience.

C. PERSONNEL ADMINISTRATION

1. Human Values

Recent Navy initiatives have struck directly at "contact point facilities," such as disbursing and personnel offices, and have had considerable impact on shipboard administration. The Chief of Naval Operations (1970a) in a personal message to all Commanding Officers encouraged improvement of standards of service at facilities which deal in services to or for people. Other directives focused on different aspects of shipboard life, and in some cases caused routines to be changed that had previously been very well established by tradition. "Z-Grams" that changed the way things were done onboard ship may have included: (in Bibliography enter with Z-(number):

Z-21 Encouraged CO's to give personnel standing holiday duty compensatory time off.

Z-25 Authorized the six-section (vice traditional four) watchbill, permitted nested ships to combine duties.

Z-29 Encouraged CO's to grant five per cent leave while ships are deployed overseas.

Z-32 Allowed person re-enlisting to arrange his own ceremony in a way pleasing to him.

Z-38 Eliminated unnecessary work on Sunday.

Z-57 Eliminated certain "Mickey Mouse" regulations.

Z-70 Defined acceptable standards of grooming and dress.

Z-92 Extended privilege of civilian clothing aboard ship to all non-rated men.

Z-106 Reiterated policy as to who should stand OOD and Quarterdeck watches in port.

Z-112 Abolished certain shipboard collateral duties.

Individually, each of these initiatives has been criticized. Collectively and with other measures they impact with positive effect on a total Navy scheme. Criticisms similarly have been aimed at ship's recreation programs, which dilute the ship's duty section or work force at inopportune times. Ship's picnics, long weekends, working parties, mess cook assignment policy: the list is seemingly endless, but each item in turn has been denounced by one or more individuals. Olmstead (1963) seemed at once to put matters in perspective when he spoke before the Navy Industrial Relations Institute:

"...organizations have a responsibility to wisely handle the human, as well as the operational, aspects of their affairs. This realization is becoming more widespread within our society, although there seems to be a continuing confusion in many organizations, both within and outside the government, as to what this means and how to accomplish it.

"Admittedly, human behavior is complex, and our knowledge of it is far from perfect. However, there is a great wealth of values, beliefs, and ideas available to draw upon in handling the human aspects of administrative responsibilities.

In this regard, I wish to suggest one major thought. There does not appear to be any one formula or set of formulas, which will provide ready-made answers to most administrative problems. This is because human behavior occurs in specific situations which have endless variety. In any situation, the following factors are always present, among others: the dimension of time--the situation has a history, a present, and a future; the physical location of the situation; the organizational purpose or mission of the unit; the equipment; the work methods and systems; the costs; the timing of controllable events; and the people present in the organization and in the related areas. Thus, it is clear that people are not the only elements which have to be considered in an organization. The manager is administering the total situation which includes both human and non-human elements."

"...administration has been studied from many viewpoints over a long period of time, and some fundamental principles are usually agreed upon as being sound. These include the desirability of a clear organizational purpose, a reasonable formal organization, intelligent planning, good work methods, and periodic review of accomplishments. HOWEVER A STRICTLY LOGICAL HANDLING OF THESE PRINCIPLES DOES NOT SEEM TO BE ALL THAT IS REQUIRED TO ACCOMPLISH AN OUTSTANDING JOB OF ADMINISTRATION. THE SUCCESSFUL INCORPORATION OF THE HUMAN FACTOR INTO ADMINISTRATION AT ALL POINTS SEEMS TO BE DESIRED BY EMPLOYEES, BY MANY MANAGEMENTS, AND BY SOCIETY IN GENERAL."

2. Systems Approach

It is the perspective from the top that the Commanding Officer has that determines the optimum "mix" between the human and non-human elements of his command. As we have seen time and again in this paper, the two are not clearly separable; and the desired objective of maximizing destroyer performance (by whatever measure chosen) will be achieved not by considering how one or the other of the elements may be affected by a particular decision, but rather by considering the total situation. It is this systems approach that is so clearly needed in the decision making process.

IX. CONCLUSION

A. APPLICATION OF BASIC FUNDAMENTALS

Reviewing human factors literature related to destroyer operations reveals a great number of conceptual ambiguities (and even methodological deficiencies). Investigators have tended to pay little attention to their dependent variables. Hypotheses were not clearly stated, and we found inadequate analyses and unwarranted conclusions. Fishbein and Ajzen (1972) in a related matter found that

> "a relatively small number of assumptions or hypotheses continue to persist in the face of repeated failures to support their validity. Instead of questioning these assumptions, investigators will discover weaknesses in previous studies and hypothesize that by making a few changes they can strengthen the procedures and increase the probability of confirming the "true" hypothesis. As Meehl (1967) pointed out,
>
> "in this fashion a zealous and clever investigator can slowly wend his way through a tenuous nomological network, performing a long series of related experiments which appear to the uncritical reader as a fine example of 'an integrated research program,' without ever once refuting or corroborating so much as a single strand of the network."

In the field of human factors, what is required are not additional studies of this type, but rather thoughtful application of basic fundamentals to the problems confronting us.

In one important respect the information contained in this paper is timeless. The subject has been the human being, and how he interacts with the equipment he operates and maintains. In fifty years, much of today's modern equipment will be obsolete, but the human factors which determine how

man will operate tomorrow's machinery are fundamental principles which will remain unchanged. We will certainly learn more about human response, and may through knowledge be able to modify certain response patterns to greater advantage than we do today, but our inborn capabilities and limitations as components in tomorrow's systems will be invariant.

B. PRACTICAL EXAMPLE OF HUMAN FACTORS METHODOLOGY

It is hoped that in many areas we can improve today's operations by greater awareness of presently known fundamentals. As a practical example consider a case where a ship has installed a remote alarm sensing panel (RASP) on the bridge, which continuously monitors the condition of the ship's navigation lights. If a light goes out, the panel automatically shifts the bulb to a secondary filament, and simultaneously gives an audible and visual indication of the problem so that maintenance personnel can respond and replace the bulb. The equipment works reliably, and over the course of a few years it seems that requiring the lookout to lean over the side of the ship every thirty minutes to inspect the light (Navy Regs, Article 1010, 1948) is superfluous. Attempting to peer through a peep-hole drilled in the deck, or holding a swab or broom over the side in an attempt to observe a reflection, is equally awkward and perhaps unnecessary with RASP. Trying to coordinate the reports of three lookouts, who are reporting the condition of no fewer than five navigational lights,

appears to be just too much for the Quartermaster of the Watch who has "more important things to do" anyway. With all the other activities of the bridge watch, wouldn't it be simpler and more efficient to simply eliminate these reports? Couldn't the OOD concentrate better on more important matters if he did not have to receive and acknowledge these seemingly trivial reports?

No matter how hectic the activity in the pilot house, often the lookout stands alone, left to his own thoughts and solo search for long periods. If watching is not challenging to him, his efficiency deteriorates by the minute. If the ship's visual search is to be effective, the lookout must be alert. Think of how important the routine requirement to have the lookout initiate a light report is in terms of maintaining his alertness. This interruption, the requirement for him to do something, will possibly reduce if not eliminate whatever decrement had built up since the beginning of his vigil. Consider the implications of this observation. In this case, we will achieve better performance (visual search) by applying our knowledge of human factors, and <u>NOT</u> letting an automatic device (RASP) take over a simple monitoring function. We also realize how to protect the lookout's night vision from the harmful effects of looking directly into these lights, and are aware of the importance of providing this protection.

C. "MAXIMUM EFFECTIVENESS FOR WAR SERVICE"

The specific question of replacing a reporting or monitoring requirement with RASP may never come up on a particular ship. But questions like it will, and the opportunity is all around us to apply the human factors principles discussed in this paper. It is common for example to find individuals who insist that the sound powered phone circuit which joins CIC and the lookouts not be used for idle chatter. "No smoking by the lookouts," and "No eating on watch," are other common commandments envoked in the name of running an efficient watch. We should question these policies in the light of human factors information presently available; and if through such questioning we begin to make certain policy adjustments, then we will have taken a first step towards reaching our goal of better destroyer operations.

As required by General Order No. 21 (Navy Regulations, 1948), the Commanding Officer shall: "Exert every effort to maintain his command in a state of maximum effectiveness for war service consistent with the degree of readiness prescribed by proper authority." Human factors will be the difference between success or failure in such efforts.

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VIGILANCE IN DESTROYER WATCHKEEPING TASKS

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A study was made of human factors affecting operations of U.S. Navy destroyers. Shipboard duties were analyzed to determine factors relevant to job performance. These factors were then considered in the light of related laboratory experiments, field and exercise results, and modern theory, to determine where improved performance could be achieved within existing personnel and material resource constraints.

Topics include vigilance and motivation; search techniques;

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PSYCHOLOGICAL STRESS (Shipboard)
HUMAN ENGINEERING (Shipboard Equipment)
MAN-MACHINES SYSTEMS EFFECTIVENESS
VISION (Thresholds, Night, Eye Scan)
HEARING (Noise, Damage, Protection)
FATIGUE (Shipboard watch schedules, sleep deprivation)
HUMAN ENGINEERING MEASURES OF EFFECTIVENESS CRITERIA
LEADERSHIP AND COUNSELING ABOARD SHIP
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PHYSICAL FITNESS AND HEALTH (Effects on Shipboard Performance)
PERSONNEL RESOURCES (Efficient Shipboard Utilization)
VIGILANCE TRAINING
RADAR OPERATOR PERFORMANCE
SONAR OPERATOR PERFORMANCE
LOOKOUT PERFORMANCE
SHIP READINESS AND HUMAN FACTORS

(20. ABSTRACT)

sensor optimization; man's total environment (factors such as fatigue, stress, lighting, temperature, noise, medication, and smoking); group and individual psychological needs; human engineering requirements; and typical performance effectiveness criteria.

The author has completed department head tours in nuclear attack submarines and guided missile frigates. He is a surface warfare specialist, qualified in submarines, and qualified for command of destroyers (189 pages plus 373 item bibliography).

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